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# Journal of the New England Water Works Association

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## OF THE
# New England Water Works Association
## 1958-1959

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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over 1000 men. Its membership is divided into six classes, viz.:

*A Member* shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

*An Honorary Member* shall be a person of acknowledged eminence in some branch of water supply or of engineering.

*A Junior* shall be not less than eighteen years and more than twenty-five years of age, a student or connected with water supply work.

*An Associate* shall be either a person, firm or corporation engaged in manufacturing or furnishing materials supplies for the construction or maintenance of water works.

*A Member Corporate* shall be either a Water Board, Commission, Company or Municipal Corporation.

The following are the annual dues as follows:

| *Admission Fees* | | *Annual Dues* | |
|---|---|---|---|
| Members | $ 3.00 | Members | $ 8.00 |
| Juniors | 1.00 | Juniors | 3.00 |
| Associates | 10.00 | Associate | 25.00 |
| Corporate Members | 10.00 | Corporate Members | 15.00 |

This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September or October on such date as the Executive Committee may designate.

**A VOTING MACHINE UNLEASHES AN ADDED 300 MILLION GALLONS OF WATER DAILY!**

A flick of a lever by an overwhelming number of New Jersey voters set in motion a long range program for supplementing the State's already over-burdened water resources with an additional 300,000,000 gallons of water per day.

The economic future of your community too, depends on far-sighted water works planning — such planning deserves to be implemented with the best — LOCK JOINT CONCRETE PRESSURE PIPE.

Durable — low cost — easily installed — LOCK JOINT CONCRETE PRESSURE PIPE, because of its minimum maintenance requirements and permanent high carrying capacity, solves tomorrow's pipe line problems TODAY, economically.

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Sales Offices: Chicago, Ill. • Columbia, S. C. • Denver, Col. • Detroit, Mich. • Hartford, Conn. • Kansas City, Mo. • Perryman, Md.

Pressure • Water • Sewer • REINFORCED CONCRETE PIPE • Culvert • Subaqueous

# BIG AD CAMPAIGN WARNS OF GROWING WATER PROBLEM!

*Urges local support for better water systems*

**Cast Iron Pipe Research Association offers local plan-of-action booklet**

Here's help for you and everyone else directly concerned with the supply, treatment and distribution of water—help that will acquaint the people in your town with the vital importance of this growing problem.

On the opposite page you see the second in a series of advertisements, this one appearing in April *Reader's Digest*. Placed by the Cast Iron Pipe Research Association, these striking advertisements point out to Mr. and Mrs. America how much we depend on a good water system and why we can no longer take it for granted.

Similar advertising will appear regularly in *U. S. News & World Report*, *Nation's Business*, *Better Homes & Gardens*, *American Home* and *Sunset* magazines to carry this public service message to millions of civic leaders and homeowners.

**Free Local How-to-Help Booklet**

These ads offer a free booklet telling about the water problem. It shows how responsible citizens can acquaint themselves with the needs of their community. It also gives a step-by-step outline of action, telling how they can help their officials extend and improve the local water system through more adequate rate structures or financing.

Let us send you a free copy of this new booklet. Write to Thos. F. Wolfe, Managing Director, Cast Iron Pipe Research Association, 3440 Prudential Plaza, Chicago 1, Ill.

***Three reasons why cast iron pipe is America's greatest water carrier:***

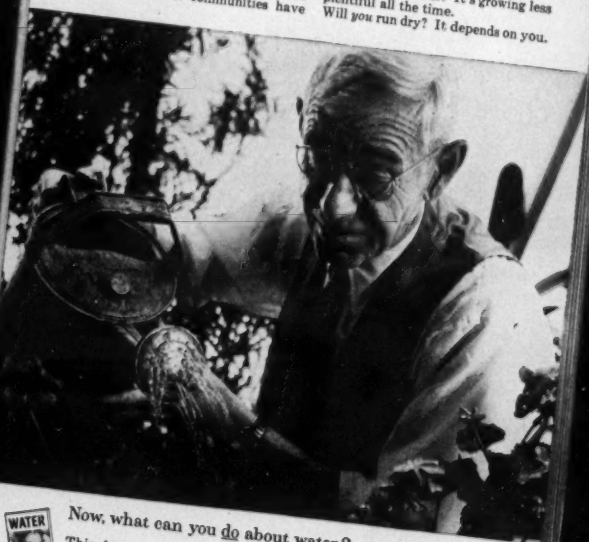
1. More miles of underground cast iron water mains are now in use than of all other kinds of pipe combined.
2. More miles of cast iron water mains are now being purchased and laid than of any other kind of pipe.
3. Impartial surveys prove that today's consulting engineers and water utility officials prefer cast iron pipe for underground water distribution by an overwhelming majority.

**CAST IRON PIPE**

Reader's

# Oh, what will you do without water?

*You mean there's a shortage?*
Indeed there is. In the last five years over 1000 U. S. communities have had to ration water. It's growing less plentiful all the time.
Will you run dry? It depends on you.

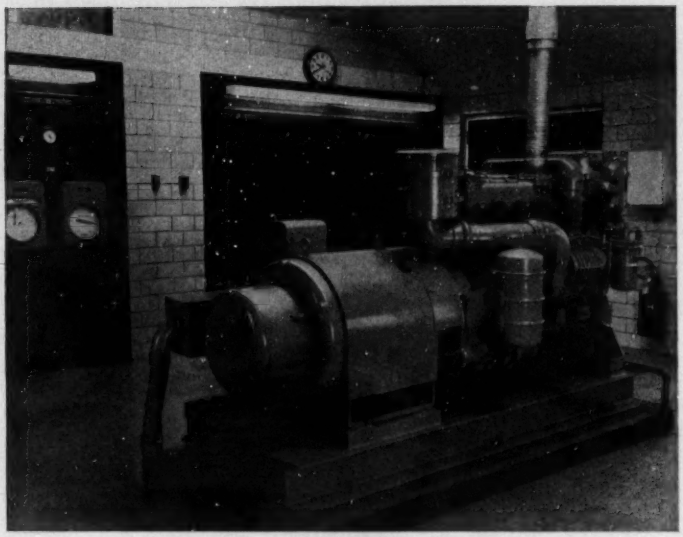


## Now, what can you do about water?

This free booklet, "*WATER—make sure you'll always have plenty,*" tells how to learn if you're running short, what to do if you are. Write Cast Iron Pipe Research Assn., Prudential Plaza, Chicago 1, Ill.

*Printed in your interest by the makers of America's greatest water carrier . . .*

**CAST IRON PIPE**



**Diesel Generator Set**
**Brunswick and Topsham Water District**
**Brunswick, Maine**

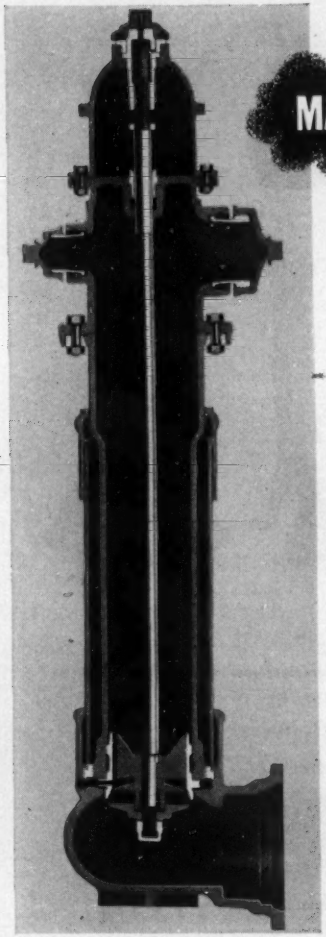
This 125 KW CUMMINS Diesel Generator Set provides stand-by power at Taylor Farm Supply, Brunswick and Topsham Water District. The generator set is specially designed to start a 100 HP pump motor.

Camp, Dresser and McKee of Boston, Massachusetts, were the engineers for this unusual application of diesel power.


**CUMMINS DIESEL OF NEW ENGLAND, INC.**
**201 Cambridge Street**
**ALLSTON 34, MASSACHUSETTS**

**106 Main Street**
**SOUTH PORTLAND, MAINE**

**720 Union Street**
**WEST SPRINGFIELD, MASSACHUSETTS**



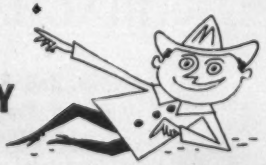
# MATHEWS HYDRANTS

**The Mathews Modernized Hydrant Supplies the 4 Fundamental Requirements for Effective Community Protection**

***and many other quality features, too***

- Replaceable barrel for maximum efficiency—quickly replaced in case of accident without excavating
- Head revolves 360°; simply loosen bolts and rotate
- Stuffing box plate cast integrally with nozzle section—eliminates extra part and provides positive, leakproof construction
- Operating thread, protected by stuffing box plate, operates free of rust, sediment and ice

Also . . . Nozzle sections supplied with hose or pumper outlets as specified • Operating thread cannot be bent • Compression-type main valve prevents broken Mathews from leaking • Nozzle level can be raised or lowered without excavating • Bell, mechanical-joint, or flange-type pipe connections • Conventional or "O" ring packings

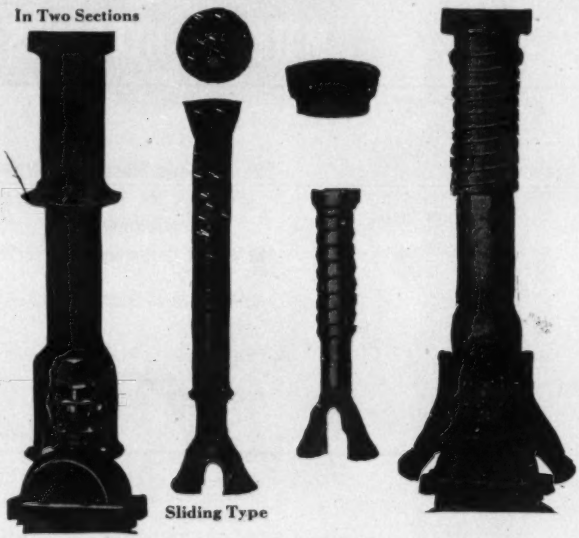


**Made by**

## R. D. WOOD COMPANY

**Public Ledger Building, Independence Square, Philadelphia 5, Pa.**

Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves

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3. *Quick Delivery*

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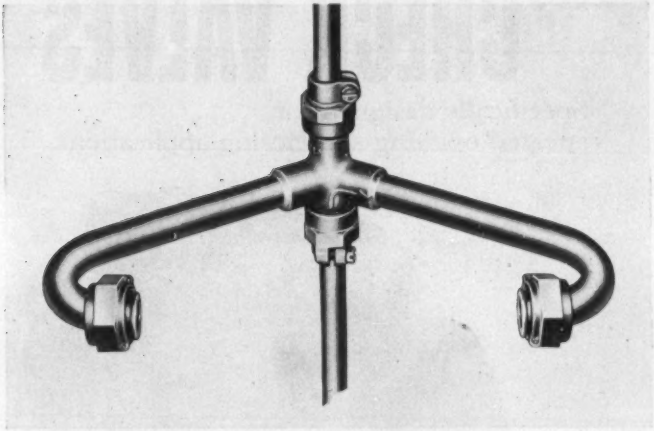
# BINGHAM & TAYLOR

CORPORATION

Genuine Buffalo Cast Iron
Service. Valve. Roadway and Meter Boxes
Manhole Frames and Covers

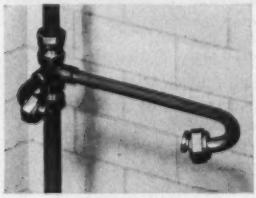
CULPEPER, VIRGINIA

# NO basement meter mounting can be installed as quickly and easily as Ford's "HANDYHORN"!



The new Ford HANDYHORN (above) eliminates pipe threading, flaring and soldering, puts meter right side up, and provides a permanent physical and electrical connection of the service even when the meter is removed.

Quickest and simplest means of setting meters in basements, the HANDY-HORN can be installed with saw and wrench. It can be used in nearly all vertical piping. Tubes are set at an angle of 120° to permit installation in corners where pipe is at least 2″ from wall surfaces.



Where piping is too close to corner . . . the Ford KORNERHORN can be employed. Like the HANDYHORN, this mount does not require flaring or soldering . . . and is quick and easy to install.

Convenient, durable and attractive, the HANDYHORN is the modern way to mount water meters . . . reduce installation costs.

**For more information, write . . .**

FORD

FOR BETTER WATER SERVICES

**THE FORD METER BOX COMPANY, INC. Wabash, Indiana**

# NEW! heavy duty MUELLER® CHECK VALVES

**Specifically designed for repeated opening and closing applications.**

*ideal for use in:*

PUMPING STATIONS
SEWAGE TREATMENT PLANTS
FILTRATION PLANTS
INDUSTRIAL PLANTS

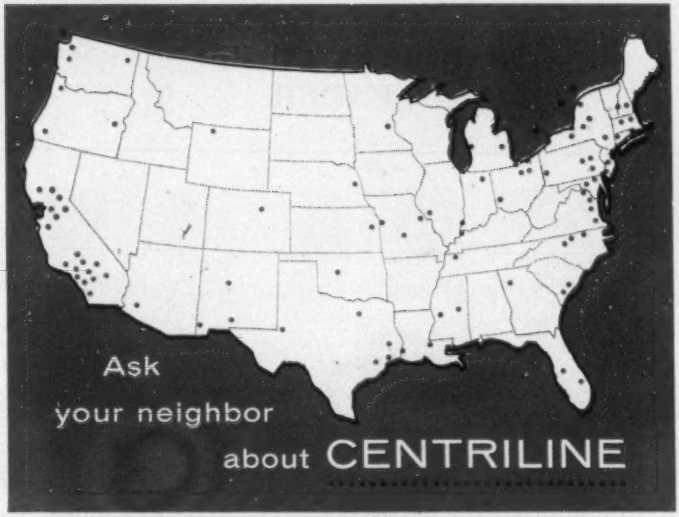
Iron Body — Bronze Mounted Flanged, Screwed or Hub Ends
Working Pressure: 175 p.s.i.
Sizes: 4", 6" and 8"

These new, heavy duty Water Works Check Valves have been specifically designed to reduce wear caused by repeated opening and closing when used in such installations as pump suction or discharge lines. All working parts are heavily constructed from high-strength materials to assure long, dependable operation without maintenance.

Write today for complete information and specifications.

**MUELLER CO. DECATUR, ILL.**

Factories at: Decatur, Chattanooga, Los Angeles; In Canada: Mueller, Limited, Sarnia, Ontario.




## Spotted on this map are some of the places that have been served by the Centriline Process

Chances are that one of your colleagues has rejuvenated some of his city's piping by Centriline reconditioning. Now here's your chance to find out.

Briefly, this process smoothly lines piping—*in place*—with cement-mortar, creating a pipe-within-a-pipe. This vastly increases carrying capacity, stops leakage, prevents corrosion and tuberculation, and prolongs pipe life indefinitely. Pressure goes up, pumping cost goes down, and there's no need to disturb traffic to replace mains. Over 6,000,000 feet of piping, from 4" to 144" diameter, have been treated by Centriline. *Ask your neighbor.*

Write today for a list of nearby officials whose cities have cut inconvenience and costs with this pipe-saving process. Hear what they have to say about Centriline. Then write or call us. We'll be glad to show you how Centriline can help *you* solve the problems of pipe reconditioning in place.

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*A Subsidiary of Raymond International Inc.*

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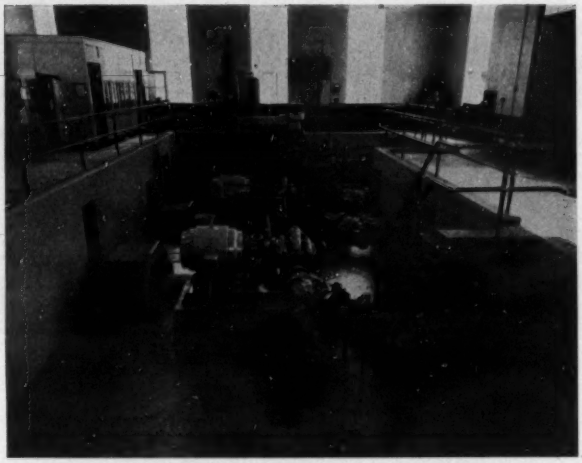
# ANOTHER FAIRBANKS-MORSE LEADER



**City of Taunton — Harris Street Pump Station**

Illustrating 2 Fairbanks-Morse motor-driven, 4 MGD Fairbanks-Morse centrifugal Figure 5814 Pumps, and 1 - 6 MGD Fairbanks-Morse 300 HP diesel-driven Fairbanks-Morse Figure 5814 Pump.

Designed and engineered by Fay, Spofford & Thorndike, Inc., Consulting Engineers.

*Write or telephone to:*

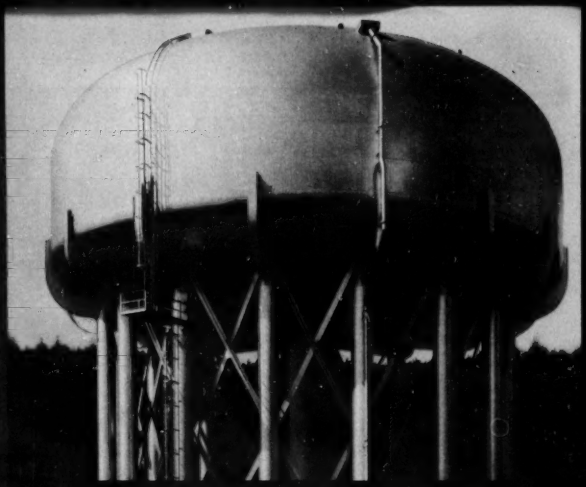
**FAIRBANKS, MORSE & CO.**

**178 Atlantic Avenue** **Boston 10, Massachusetts**

**Telephone: LAfayette 3-3600**

PDM
ELEVATED STEEL TANKS

# ELEVATED STEEL TANKS



Radial cone tank, Seattle, Wash. Capacity 2,000,000 gallons.

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**TO SERVE DEPENDABLY THE WATER STORAGE NEEDS OF MODERN AMERICAN COMMUNITIES**

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From the first PDM Elevated Steel Tank, pioneered in 1897, to the handsome structures of the present, *first quality* has been our continually-realized objective. You'll find in the wide range of PDM tank types and capacities the ideal unit for your requirements—guaranteed in performance and satisfaction. Let us submit a quotation.

Toro-segmental tank, Sioux City, Ia. Capacity 2,000,000 gallons.

Radial cone tank, Independence, Kansas. Capacity 750,000 gallons.

Double-ellipsoidal tank, Melbourne, Fla. Capacity 300,000 gallons.

Pedestal sphere, Hawthorne, Calif. Capacity 250,000 gallons.

RITE FOR this fully-lustrated 28-page Modern Water Storage" ochure—detailing the nge of PDM Elevated el Tanks. Free on re-uest to our nearest fice.

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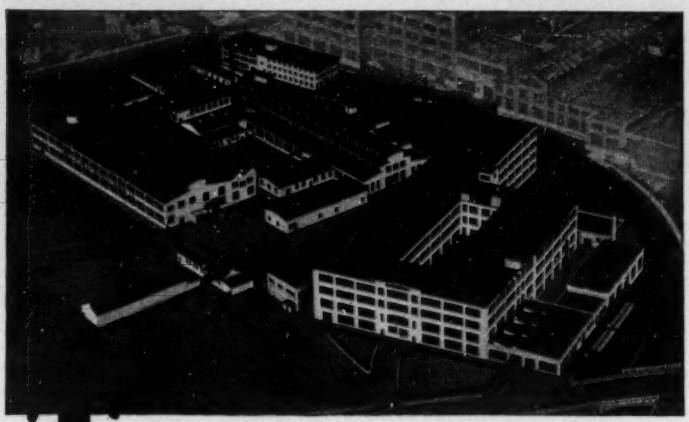
DENVER (2)...323 Railway Exchange Bldg.



# THE A. P. SMITH MANUFACTURING CO.

produces, FIRE HYDRANTS A. W. W. A. Specification and High Pressure — Compression Type — Dry and Wet Barrel Types. GATE VALVES sizes 2" thru 66", Manual, Hydraulic Cylinder, Electric Motor Operated for Low, Medium and High Pressure Service. INSERTING VALVES sizes 4" thru 48" for inserting under pressure. TAPPING SLEEVE AND VALVES sizes 4" x 2" thru 60" x 48" for branch connections under pressure.

42

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*it's a snap!*

*with a*

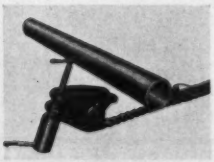
# WHEELER HYDRAULIC PIPE CUTTER

**NO VISE — NO TURNING — JUST SQUEEZE AND POP!**

**Cutter can be used in a ditch to cut pipe in a line with minimum clearance. All that's required is room to wrap the chain around the pipe.**

**THE HYDRAULIC MODEL CUTS —**

- **CLASS 150 AWWA WATER MAIN 4" thru 12"**
- **CLASS 250 AWWA WATER MAIN 4" thru 12"**
- **CEMENT LINED CAST IRON WATER MAIN 4" thru 12"**
- **STD. OR XH SOIL PIPE 6" thru 15"**
- **ASBESTOS CEMENT PRESSURE PIPE 6" thru 10"**



**— less than 2 minutes per cut —**
**a one man operation.**

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*Lick the problem of fogged registers*

**HERMETICALLY SEALED REGISTER IS DRIVEN BY THE POWERFUL BOND OF A MAGNETIC COUPLING**

**You can lick the problem of fogged registers.** Get Rockwell Sealed Register Meters. Then dirt and moisture will be no more. That's because the register is hermetically sealed to prevent condensation.

Get these other advances, too. Get the only meter with magnetic drive . . . the only meter with instrument type gearing . . . . the only meter with but two parts operating in water . . . the only meter without a stuffing box.

And with Rockwell Sealed Register Meters you'll get less wear, less corrosion, easier maintenance at lower cost. Write Rockwell Manufacturing Co., Pittsburgh 8, Pa.

**Now available in both ⅝" and full ¾" sizes**

SEALED REGISTER METERS

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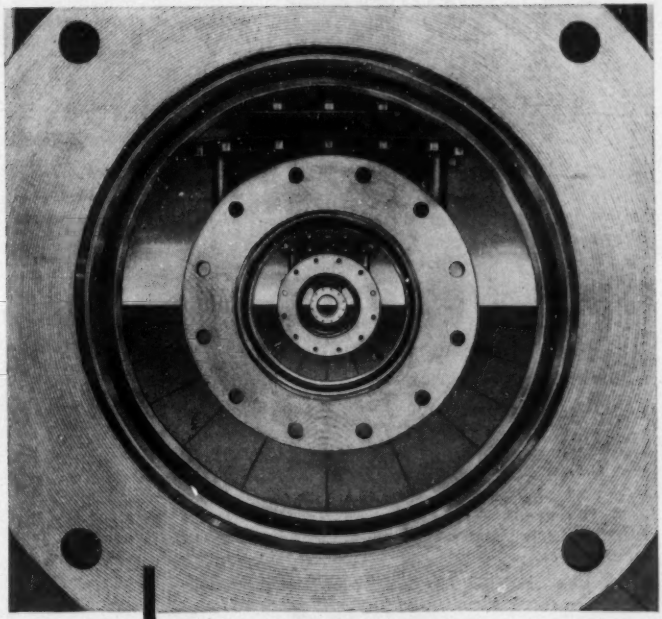

## Through these Gate Valves pass the best-regulated streams in the World!

The sound design and quality-workmanship of Ludlow gate valves and Rensselaer gate valves is a guarantee of *lasting* ease of operation. Watertight closure is assured through years of trouble-free performance.

Write for the L&R Gate Valve Catalogs, showing the most complete selection of outstanding design features available today. Ludlow and Rensselaer double disc gate valves meet all requirements, including A.W.W.A. specifications, in sizes from 2" to 72", plus custom designing for special applications.

LUDLOW & RENSSELAER

VALVES AND HYDRANTS

THE LUDLOW VALVE MANUFACTURING CO., INC., TROY, N. Y. – SINCE 1861

# The meter you buy today...

## will it meet *1988* standards?

When buying new water meters, a most important question of cost is: "In 30 years will this meter be *scrapped*, or will it be rebuilt to *1988* standards at a fraction of the cost . . . ready for years more accurate service?"

Take a look at the *past* 30 years. Think how much you're saving *this* year on Trident meters installed back in 1928 . . . or even 30 years before that.

Under Trident's strict policy of interchangeability, all improved parts are designed to fit old Tridents too. These up-to-date Trident parts embody every thoroughly tested advancement known to metering science. Not only is repairing easy and economical, but also you actually modernize your Tridents as you go.

This has been a rigid Neptune policy for 60 years. *Every design improvement now on our drawing boards will continue it.* It's your best assurance that the Tridents you buy today will stay modern, earning maximum revenue for your water system . . . at lowest cost . . . for many years to come.

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*The story of how composite, wire-wound prestressed liquid storage tanks can effect substantial savings for you is worth knowing. For full information, write to:*

**NATGUN CORPORATION**
101 West Dedham Street,
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## BEST ANSWERED OUR NEED FOR ECONOMY"

When the West Boylston Water District* decided in favor of a new storage tank, its unanimous choice was for the NATGUN prestressed tank. This prestressed tank, 100% maintenance-free, best answered our need for economy. Put into service in 1957, we anticipate that our 500,000 gallon prestressed tank will give us long years of trouble-free service with no mounting maintenance costs to worry about.

*Consulting Engineers
WHITMAN & HOWARD
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LOUIS CAMPBELL
*Superintendent*

In ever-increasing numbers, prestressed tanks are springing up across the country. The answer is simple:

- Steel tanks never stop costing
- Prestressed tanks cost only once

**A 100% MAINTENANCE-FREE** PRESTRESSED TANK **CONSTRUCTION MEANS:**

- **NO RUSTING**
- **NO PAINTING**
- **NO DANGEROUS AND TROUBLESOME DOWN TIME**

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of

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Manufacturers of

## CAST IRON PIPE & FITTINGS

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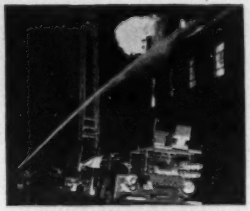
**THE BUCKET BRIGADE** of earlier days was willing but ineffective. Once started, a blaze usually raged to complete destruction.



**MODERN FIRE FIGHTING APPARATUS**, fed by a dependable water system of cast iron pipe, uses high pressure to place water where needed. Losses are minimized.

**U.S. cast iron PIPE**

**FOR WATER, SEWERAGE AND**

**U. S. PIPE AND FOUNDRY COMPANY**

# but better than ever today!

**Top quality of U. S. Pipe assured by rigid mine-to-main supervision**

Cast iron pipe may look alike.

But there's a difference... an important difference to the men charged with keeping our water running smoothly — the nation's water officials.

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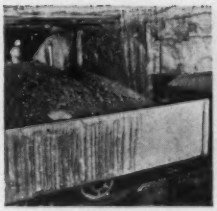

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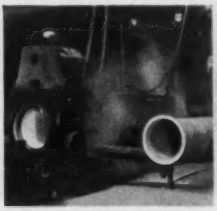

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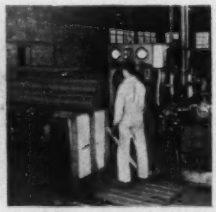

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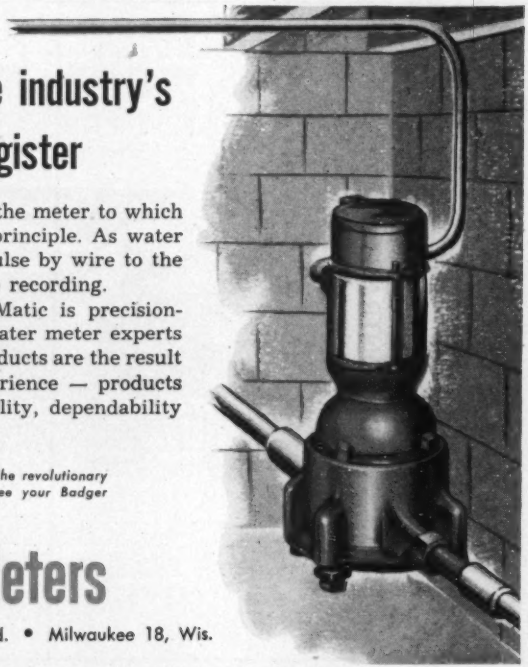

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NEW ENGLAND WATER WORKS ASSOCIATION
ORGANIZED 1882

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# WEST SPRINGFIELD'S WATER SUPPLY

BY PHILIP W. SHERIDAN*

[*Read April 17, 1958.*]

The town of West Springfield obtains its supply of water from two sources. The first source developed is a source water supply, located on Paucatuck Brook in the western part of the town, and is commonly referred to as the "Bear Hole" supply. A second source developed in the 1930's by Supt. Theodore Beach, now retired, is a ground-water supply, located in the town of Southwick approximately seven miles west of West Springfield, and is commonly referred to as the "Southwick" supply.

During 1954-1955, the town spent approximately $1,300,000 on the supply and distribution system. The Southwick supply was renovated, and three new pumping stations were constructed so as to pump automatically into the distribution system through the existing 16-inch cast-iron transmission main.

This $1,300,000 improvement program was just about complete when the 1955 flood struck. The Southwick supply was made inoperative by the flooding to various degrees of the three pumping stations and the rupturing of the transmission main at two locations. The damage was related to the failure of a dike on the Congamond Lakes. At the same time, the Bear Hole dam failed and wiped out the filter plant. Thus both parts of the town's independent supply were placed out of service by a single natural disaster.

Emergency connections with the city of Springfield's transmission main were opened. This source of water supplied West Springfield for a period of approximately one week. During this time, emergency repairs were made to the Southwick supply's transmission main and pumping stations. From then until late

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1957, the town was entirely dependent on the Southwick supply (with the Springfield connections held in reserve), while the Bear Hole supply was being rebuilt.

The Bear Hole Filter Plant was originally established in 1906 as a slow-sand filter plant. The installation consisted of a single, open filter bed and a pumping station to discharge the filtered water to the distribution system. A low wooden dam was constructed on Paucatuck Brook upstream of the filter-plant location. Raw water was supplied to the filter bed by gravity through a vitrified-clay pipeline.

Additions and improvements were made to the dam, filter plant and pumping station at various times through the years. At the time of the 1955 flood, the installation consisted of a 28-foot earthen dam, containing a reservoir of 57 mil gal; three open, slow-sand filter beds totaling 0.75 acres, and a pumping station containing two, electrically-driven, 3-mgd pumps. While the installation was effective and produced a water of very satisfactory quality, it was generally recognized that the installation was obsolete and in need of extensive repair and renovation work.

The August, 1955, flood breached the dam. The released flood of water swept down the valley and almost completely obliterated the filter beds. The brick walls of the pumping station were left standing, but all the equipment was flooded and suffered extensive damage.

Almost immediately after the flood, engineering studies covering repair or replacement of the installation were undertaken. The State Legislature passed an act allocating a sum of money for the repair of *flood damage*. This act was administered by the Flood Relief Board, and a general policy was established that damaged installations were to be repaired or replaced "in kind." No *improvements* could be financed under the Flood Relief Act.

The Flood Relief Act was administered with intelligence and cooperation. It was recognized that the replacement of outmoded equipment or installations "in kind" would be expensive. In general, a certain amount of leeway was allowed in replacing outmoded equipment or installations with modern equipment and installations.

Initial engineering studies were concentrated on cost comparisons of three plans—namely: one, the reconstruction of the

slow-sand filter plant; two, the construction of a rapid-sand filter plant; and three, the abandonment of Bear Hole as a source of supply and the enlargement of West Springfield's well field, located in the town of Southwick.

It was recognized that even if a slow-sand filter plant of the same general size and capacity as the damaged plant was constructed, the town would have to make a substantial contribution toward the construction cost, to cover the cost of certain improvements. In general, these improvements consisted of the provision of stand-by power in the pumping station and the provision of automatic controls for the filter plant and pumping station.

From the long-range financial point of view, the town would have been best served if Bear Hole had been entirely abandoned and the Southwick Well Field supply enlarged. The capital investment per mgd of safe yield produced was substantially lower for the Southwick Well Field supply than for any scheme developed for the Bear Hole supply.

In order to develop the Southwick Well Field supply further, a 7-mile-long transmission main was required to supplement the existing 16-inch transmission main. The demand for additional water in excess of the existing Southwick supply was small and could easily be met by the Bear Hole supply with its safe yield of 1.25 mgd. The town's ultimate water needs would require the expansion of the Southwick supply to its full potential. In developing construction costs for the engineering comparisons, the transmission main was sized at 24-inch. This proposed new main, together with the existing 16-inch main, could carry the entire potential of the Southwick Well Field installation. This new pipeline, together with two new deep-well pumping stations, was estimated to cost $670,000 and would have supplied 5 mgd of additional water to the system. The capital cost of development would thus be approximately $134,000 per mgd of safe yield.

The Bear Hole development was estimated to cost $388,000 for a safe yield of 1.25 mgd. The capital cost of development would thus be approximately $310,000 per mgd of safe yield.

A factor considered in making the final selection was the gradually decreasing quality of the run-off from the Bear Hole drainage area and the increasing pressure to make the Bear Hole area available for recreational and residential development.

A second factor considered was the advisability of maintaining two sources of supply, as compared to abandoning Bear Hole and placing full reliance on the Southwick supply. The Southwick supply was considered to be somewhat vulnerable because of the long transmission main. The quality of the water obtained from the Southwick supply is excellent and requires neither treatment nor chlorination.

The decision in favor of reconstructing the Bear Hole supply was finally made, based mostly on financial considerations. The town had just completed a water-system improvement program under a $1,300,000, 15-year bond issue. It was the opinion of town officials that another water bond issue should not be floated until the present Water Department bonded indebtedness had been substantially reduced.

Engineering study indicated that reconstruction of Bear Hole, together with the existing Southwick development, would provide the town with sufficient water supplies to carry it through the life of the existing bond issues. The town's share of the Bear Hole reconstruction cost, representing improvements in the filter plant and pumping station, was estimated to be under $100,000 and could be financed directly from taxation. The town's share of the additional Southwick development was estimated to be in the range of $400,000 and would have required a bond issue.

Once it was decided to proceed with the reconstruction of the Bear Hole facility, further detailed studies were made of a slow-sand filter plant as compared to a rapid-sand filter plant. These studies resulted in a decision to construct a slow-sand filter plant very similar to the flood-damaged plant. To have changed to a rapid-sand filter plant would have complicated the negotiations with the State Flood Relief Board. It developed that there would be no substantial saving in construction cost, as a result of building a rapid-sand filter plant instead of a slow-sand filter plant. The close cost comparison of the two types of plants was the result of using "open" slow-sand filters and retaining the damaged clear-water well, after repairs, in the new plant.

The flood-damaged pumping station contained two electrically driven, manually operated, centrifugal, two-stage pumps. These pumps operated under a vacuum lift of 10″ to 15″ Hg. The old station was constructed with a depressed pump floor, approx-

imately four feet below the grade of the grounds outside the building. The pump-room floor grade was at an elevation only slightly above the Paucatuck Brook flow line. This arrangement was hazardous to the pumping station. Either a broken pipe within the pumping station or flood conditions in the brook could cause, and had caused, extensive damage to the station equipment.

Hydraulic studies were carried out of the flow line or gradient from the reservoir, through the piping system and filters and to the clear-water well. These studies established operating limits for water level in the clear-water well. These were especially critical during drought periods when the reservoir water level would be low.

Further engineering studies were made of the grading of the plant area and of the water levels in Paucatuck Brook under various flood conditions. Based on these studies, an elevation for the pump-room floor in the new pumping station was selected.

The selection of vertical turbine pumping equipment for the pumping station has been based mainly on the relative elevations of the pump-room floor and the water level in the clear-water well. In addition to the high suction lift imposed on standard centrifugal pumps by these elevations, factors also considered included the space limitations of the pumping station, the presence of three other vertical turbine pumping stations in the West Springfield system, and the relative cost of vertical turbine pumping equipment as compared to centrifugal pumps.

The final decision on pumping equipment was to install a pair of 2-mgd, vertical turbine pumps, each equipped with right-angle gear and diesel engine stand-by unit. Space and piping connections are provided for a third pumping unit of the same size, which would be installed at some future date after enlargement of the filter plant and raising of the dam.

The raw-water supply for the filter plant is obtained from the impounded waters of Paucatuck Brook. The new dam is of the same general size and construction as the dam breached in the 1955 flood. The dam is located on a drainage area containing approximately 5.5 sq mi. The upper 2.5 sq mi of drainage area are controlled by the city of Holyoke's Ashley Pond water-supply reservoir. Thus, the safe yield of the Bear Hole supply is based on a drainage area of 3.0 sq mi, with flood flow for spillway de-

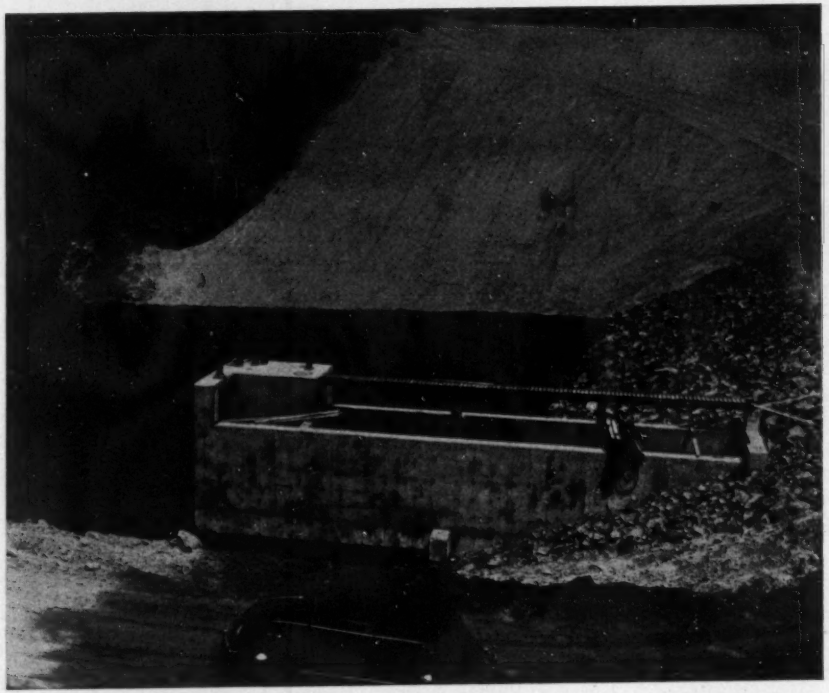
sign based on a 5.5-sq mi drainage area. The valley itself at the dam location is very narrow. The length of the dam is only 250 ft, with a total height of 34 ft above stream bed.

The dam is located immediately upstream of the filter plant. The valley presented some problems complicating the design and construction of the dam. In general, the old glacier valley is located far to the east of the present valley. The west side of the present valley consists of approximately 5 ft of glacial till over traprock, and presented an ideal west abutment for the dam. This glacial till and traprock continue to dip down steeply below the bottom of the present valley. The east abutment appeared to be the remains of a delta and consisted of a sandy or pervious material, interlaid with occasional thin layers of clay. The bottom of the present valley is filled with a soft clay which, under the proposed dam location, had a depth of 30 ft to 50 ft.

The new dam consists of an impervious earthen core, constructed of glacial till obtained from the west side of the valley above and upstream of the dam location. The remaining portion of the dam, both upstream and downstream, was constructed of the sandy or pervious material obtained from the east sidehill location. The impervious core was carried down to and keyed into the soft clay underneath the dam location. The tie between the impervious core and the pervious material in the east sidehill was made with a short line of steel sheet piling, driven so as to lengthen the seepage path through the east abutment and decrease the seepage rate. Care was taken to place the impervious core in a relatively plastic condition and to carry the impervious and pervious soil levels at the same elevation during construction, so as to minimize difficulties resulting from compaction or movement of the soft clay foundation of the dam.

The intake structure for the filter plant and the overflow spillway for the dam were combined into a single unit and were located on the westerly end of the dam (see Fig. 1). In this location, it was possible to found these structures on the solid traprock. The overflow structure included a sluice gate for the emptying of the reservoir. This sluice gate was used as a diversion gate during construction of the earthen portion of the dam.

In construction of the dam, the contractor had considerable difficulty because of the soft foundation condition. However, once



*Neil Doherty*

FIG. 1.—GENERAL VIEW OF UPSTREAM FACE OF BEAR HOLE DAM, CONCRETE SPILLWAY AND INTAKE STRUCTURE

the earthwork was brought above the level of the soft clay, construction proceeded at a rapid rate. The presence of the impervious material at the west abutment and the pervious material at the east abutment made construction a relatively routine matter. Construction began in the late summer of 1956 and was carried on continuously until completion in the early summer of 1957, with the exception of a short shutdown for freezing weather during the winter.

Construction contract for the dam was awarded in midsummer of 1956. The construction contract for the filter plant was awarded in the late fall of 1956. The same contractor was low bidder on both projects and received both contracts.

On the filter plant, the contractor carried on pipeline, drainage and foundation work during the winter of 1956-57. Arrival of good weather in early 1957 saw an increase in the tempo of construction activity, and the plant began to take shape.

Approximately 1,100 ft of 10-feet-high cantilever retaining wall were constructed around the three open filter beds. In addition to this concrete, additional concrete work was required in the pumping-station substructure and in the various valve pits located throughout the filter plant. A total of approximately 1,500 cu yd of concrete was placed under the filter-plant contract.

The raw water for the filter plant is drawn from the intake structure, located as an integral part of the overflow spillway at the dam. This intake structure is equipped with sluice gates for drawing the reservoir water from either the mid-depth or the bottom of the pond. It is expected that under normal operation water will be drawn from the mid-depth intake, and that only during severe drought will water be drawn from the bottom of the reservoir. The intake structure includes a dual set of ¼-inch-mesh aluminum screens, to prevent the entrance of debris and leaves into the filter-plant raw-water piping system.

An unusual feature of the intake structure is the provision of a method of backflushing the screens. By closing sluice gates on the intake and outlet of the gatehouse and opening the drain valve provided, it is possible to draw reservoir water backwards through the screens. This arrangement permits the removal of the major portion of any material caught on the screens. To date

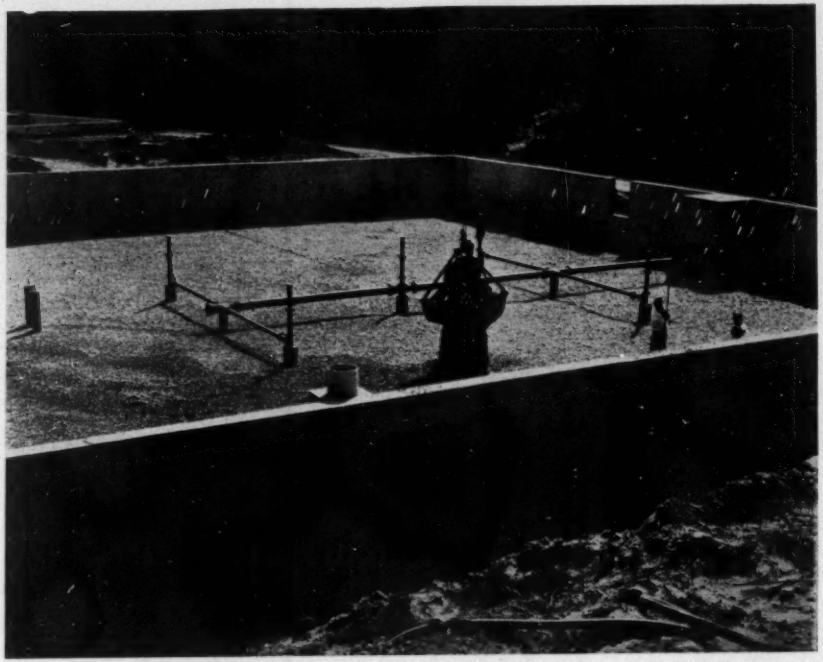
it has not been necessary to remove these screens for manual cleaning.

The filter plant in existence prior to the flood included a spray-type aeration unit. However, due to the low head available from the dam and the limited size of the aeration unit and its related piping, operation of the old aeration unit was not always possible. Many times it was necessary to bypass the aeration unit in the old plant, in order to obtain sufficient water for the operation of the sand filter beds themselves. The hydraulic studies previously referred to, in order to determine gradient through the filter plant, indicated that this same condition would occur in the re-designed filter plant.

Because of this condition, it was finally decided to eliminate any design based on a separate aeration unit. The aeration function was combined with the discharge of water onto the filter beds. This arrangement made it possible to design the plant to include aeration for all water levels in the reservoir down to mid-depth of the reservoir. Generally speaking, when the reservoir level is drawn below the mid-point, it will be necessary to remove the aeration units from operation and to discharge the raw water directly onto the filter beds.

The raw water is brought onto the filter beds through a network of pipes serving five discharge points (see Fig. 2). Each of these discharge points is brought to an elevation slightly above the water level on the top of the filter and is equipped with a spray nozzle. Thus, the water entering the filter beds is first sprayed into the air in the form of a fine mist or droplets. This mist is then allowed to fall onto the water on the filter bed. This arrangement has the disadvantage of producing a minor amount of turbulence in the raw water on the filter bed, but this turbulence does not appear to have any adverse effect on the filter-bed operation. The arrangement has the advantage of introducing raw water more evenly across the entire filter-bed area and results in relatively uniform clogging of the filter bed, as compared to the usual inlet arrangements.

The raw-water level on each of the filter beds is individually controlled by a float-operated, globe-type valve, located on the raw-water line feeding the filter. This valve is located in a cham-



*Neil Doherty*

FIG. 2.—VIEW OF FILTER BED AT BEAR HOLE FILTER PLANT, SHOWING GENERAL ARRANGEMENT OF RAW-WATER PIPING AND FIVE AERATION POINTS. (Washed gravel underdrainage material being placed by crane.)

ber constructed beside the filter being served, with piping connections for the float carried directly to the water on the filter bed.

The filter sand on each of the beds is approximately 40 in. thick. This filter sand has an effective size of 0.42 mm and a uniformity coefficient of 3.0. The sand is a washed and screened sand, obtained from a nearby pit. It was processed as a "concrete" sand but was found suitable for use in the filter bed.

The filter sand is supported by approximately 18 in. of graded, washed stone, placed in 3-in. layers of varying size. The underdrainage system for the collection of filtered water consists of split 8-in. vitrified-clay pipe, feeding to a central channel. The discharge from the beds is controlled semi-automatically by overflow weirs. However, the discharge from each bed is controlled by a hydraulic cylinder-operated gate valve, actuated by the water level in the clear-water well.

The pumping station is normally operated by electric power and is fully automatic under this arrangement. The pumps are started and stopped by remote control, actuated by the water level in the storage tanks.

The operation using the standby diesel engines is an entirely manual arrangement. The drive arrangement itself must be manually changed by the movement of a sliding clutch at the right-angle gear. The diesels are then started manually. Sufficient fuel-oil storage for the diesels has been provided for approximately 30 days of operation.

In summary, the reconstructed Bear Hole water-supply facility has a safe yield of approximately 1.5 mgd. The filter plant can handle rates of approximately double the safe yield. A general view of the Bear Hole Dam and Filter Plant is shown in Fig. 3.

Together with the well-field installation at Southwick, the West Springfield system has a safe yield of approximately 5 mgd and a pumping capacity of approximately 8 mgd. These two water-supply facilities pump directly to the distribution system. Storage on the distribution system itself consists of a 105-ft-diameter by 62-ft-high, 4-mil gal steel storage tank on Rogers Ave.; a 120-ft-diameter by 48-ft-high, 4-mil gal steel storage tank on Pease Ave., and a 62-ft-diameter by 45-ft-high, 1-mil gal steel storage tank on Birnie Ave. These storage tanks are located

*Neil Doherty*

FIG. 3.—AERIAL VIEW OF RESERVOIR, DAM AND FILTER PLANT. (Construction of dam completed and reservoir being filled. Construction of filter plant nearing completion.)

roughly in a north-south line and extend the entire length of the distribution system.

Considering the fact that the average daily demand on a yearly basis in the West Springfield system is now approximately 3 mgd, it is apparent that the improvements undertaken by West Springfield will result in an adequate supply of high-quality water, delivered at good pressure, for many years to come.

# OCCURRENCE OF WATER IN BURIED-VALLEY DEPOSITS

BY DAVID W. MILLER*

[*Read September 15, 1958.*]

The continuing emphasis on construction of dams and reservoirs, which is based on an understandable desire to make use of visible water supplies, often obscures the fact that prodigious quantities of ground water are available in many areas near or at the points of distribution. The lack of appreciation for the ground-water potential in these areas stems from the fact that ground water is a hidden resource and cannot be evaluated except by a thorough investigation of geologic and hydrologic conditions. Because these conditions vary, ground water is readily available in some localities, whereas in other places it is difficult to obtain even small supplies.

Owing to the diversified character of water-bearing materials and variations in geologic structure, there are many types of ground-water reservoirs. Sand and gravel deposits, in contrast to solid rock formations, supply by far the most ground water to wells in the United States. In many parts of the country, such as the coastal plain region, thick and extensive deposits of sand and gravel underlie the land surface and contain large quantities of ground water. In other areas, however, deposits of sand and gravel are not widespread, and their presence may not be readily apparent from an inspection of the land surface. This condition is particularly common in the northern part of the United States, where many ancient bedrock valleys are filled with good water-bearing deposits of sand and gravel. It is the purpose of this paper to describe the principles of ground-water occurrence in the buried-valley type of ground-water reservoir and to show its importance as a source of water supply.

In the northern part of the United States the landscape has been shaped and modified principally by two geologic agents,

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running water and glacial ice. Before the great continental ice sheets invaded this region from Canada many thousands of years ago, during the period of time referred to as the Pleistocene Epoch, stream valleys and gorges had been eroded in the consolidated rock formations which then lay at land surface. The erosion had continued almost without interruption for hundreds of thousands of years before the ice advance and had produced a well-established drainage pattern.

The episode of glaciation came as the result of a climatic change that caused snow and ice to accumulate in Canada to such a depth that a continental ice sheet developed and extended southward over the northern part of the United States. The slowly moving ice streamlined the shapes of hills and modified in a minor way the outlines of existing valleys. The erosive action of the ice sheet also resulted in the scraping away of most of the previously formed soil.

From a ground-water standpoint, the most important work done by the ice was the deposition of sand, gravel and clay over a wide region. These glacial materials are referred to as drift and are generally classified into two types, till and outwash. Till consists of unsorted rock fragments of all sizes, including boulders, gravel, sand and clay deposited directly by the retreating glaciers. This material is unsorted and unstratified and is therefore relatively impermeable. Outwash, on the other hand, consists of sorted and stratified materials deposited by meltwater streams flowing from the ice mass. These streams transported rock debris which was later deposited as separate layers of gravel, sand or clay in the stream valleys, on the flood plains, and beyond the ice front. The layers of sand and gravel are generally very permeable, and where they are thick and widespread are capable of storing and transmitting large quantities of ground water. The maximum extent of the ice sheets in the United States and the principal areas underlain by glacial drift are shown in Figure 1.

Some of the most important deposits of outwash material, with respect to ground-water development, are those in the preglacial valleys. During both the advance and retreat of the glaciers, these valleys were either partially filled with outwash or were completely buried under the sand, gravel and finer materials. These glacial outwash materials are often referred to as

FIG. 1.—EXTENT OF PLEISTOCENE ICE SHEET IN THE UNITED STATES.
*(After unpublished map compiled by W. C. Alden.)*

valley-train deposits. Since glacial time, streams have re-established themselves in the remnants of the former topography, and some of these streams roughly follow the courses of the pre-glacial streams. However, in many areas, the present drainage pattern does not conform to the buried pre-glacial drainage pattern, and the buried valleys may be many miles away from existing watercourses.

Buried-valley deposits constitute some of the most prolific aquifers over the greater portion of this country's glaciated region. They are extensive in many states, and numerous large ground-water supplies have already been developed in them. For example, Figure 2 shows the present drainage pattern in Montgomery County, Ohio, superimposed over the outlines of the known buried valleys. In that area, ground-water pumpage is concentrated in the valley-train deposits from Dayton south to Miamisburg and averages about 90 to 100 mgd. Most of the wells are between 80 and 120 ft deep and individually yield between 750 and 1,500 gpm. Yields of some wells in the buried-valley deposits are greater than 4,000 gpm.

The system of broad and extensive buried valleys illustrated in Figure 2 is more or less typical of conditions in much of the glaciated central region, especially in Michigan and parts of Indiana, Ohio, Illinois, Wisconsin, Iowa, Minnesota and western New York. In many of the principal cities in this region, such as Sioux City, Indianapolis, Kalamazoo and Peoria, pumpage from wells exceeds 25 mgd. Even in the immediately adjacent states, where the glacial drift is generally thinner and less effective as a reservoir, there are many channels filled with glacial outwash in which large ground-water supplies are found.

Glacial outwash material, especially where it occurs as thick valley-train deposits, is also the most productive aquifer of the glaciated Appalachian region, which includes practically all of New England plus the eastern part of New York and the northern parts of Pennsylvania and New Jersey. Although the buried valleys in these areas, with some important exceptions, are not as broad and extensive as those found in the glaciated central region, many of them contain thick permeable beds of sand and gravel. Numerous cities and industries in the glaciated Appalachian region already depend upon wells in buried valleys. However, few

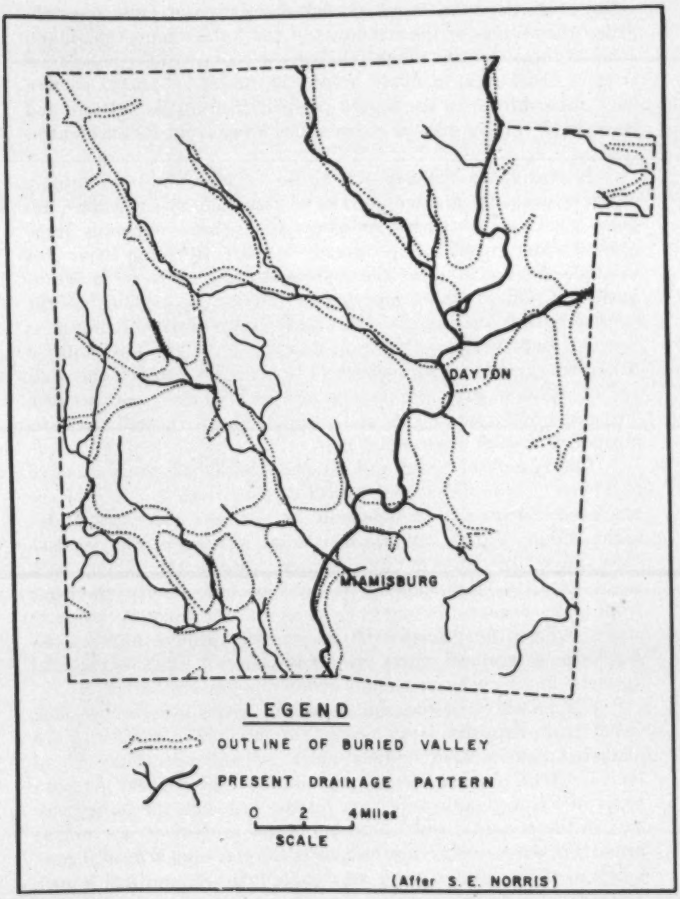


FIG. 2.—LOCATION OF PRESENT DRAINAGE AND BURIED VALLEYS, MONTGOMERY COUNTY, OHIO.

of the numerous valley-train deposits have been developed to their full capacities, and many have not even been explored for their ground-water potential.

Figure 3 shows the profile of a buried valley underlying the Blackstone River in Woonsocket, R. I. This profile is typical of many of the buried valleys throughout New England and shows the tremendous size of the ground-water reservoir on which the narrow channel of the Blackstone River is located. Natural recharge from rainfall and the large storage capacity of the ground-water reservoir permit the location of high-capacity wells almost anywhere in the deeper parts of the buried valley. Wells located very close to the Blackstone River may receive an added benefit from induced infiltration of river water.

The presence of buried valleys in a specific area can sometimes be determined from surface indications. In regions where the pre-glacial drainage pattern is a dominant topographic feature, a close examination of topographic maps will often give much valuable evidence concerning the existence of buried-valley deposits. However, map interpretation alone is not adequate for outlining the areal extent of valley-train deposits and should be supplemented by a study of well logs and well information.

In some states, much of this information is on file with state and federal agencies or is already published in geologic and water-resource bulletins. However, a ground-water inventory usually is needed, to provide basic data on local geology, well yields, and ground-water conditions. The ground-water inventory normally involves a field reconnaissance and the collection of well records from such sources as individual well owners and local water-well contractors. Once the available basic data have been collected and a general knowledge of the geology of the region has been gained, it is then necessary to choose the specific areas in which to prospect for ground-water supplies.

Perhaps the best method for illustrating some of the steps to be taken in locating and developing ground-water supplies in buried-valley deposits is to describe briefly a recent investigation directed toward the expansion of ground-water facilities in Essex and Morris Counties, New Jersey. These facilities, owned by the city of East Orange, are situated in the Passaic River Valley about 10 miles west of Newark, N. J. Yields of the original wells

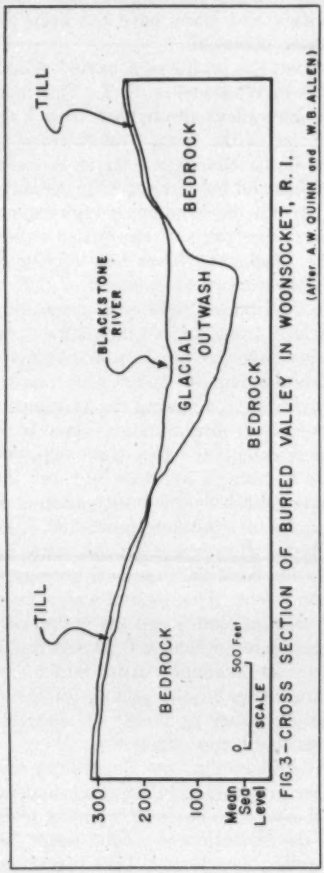


FIG.3-CROSS SECTION OF BURIED VALLEY IN WOONSOCKET, R. I.
(After A.W. QUINN and W.B. ALLEN)

in the bedrock sandstones and shales averaged 100 to 200 gpm, while individual production wells already located in the buried valley shown on Figure 4 had been pumped at 1,000 gpm for many years. Therefore, it was decided that new well construction should be limited to the buried-valley system.

There is little surface indication of the configuration of the buried bedrock floor, and the original well-log data, although helpful, were inadequate to show the extent of the buried valley and the best sites for drilling new wells. Data from electrical resistivity surveys in the area were also available, but test drilling showed that the resistivity information was unreliable. Before additional test wells were drilled, it was decided that much valuable time and expense could be saved by attempting to define the shape of the buried valley by means of the seismic method of geophysical prospecting. Accordingly, a seismic survey was undertaken in the general vicinity of the original well field. The interpretation of the seismic data provided considerable information on the depth to bedrock and the configuration of the rock floor over a broad area, and was used to select specific sites for test drilling. In all, eight test wells were drilled through the unconsolidated material to bedrock, so that samples of the glacial material could be collected and analyzed. The depths to bedrock determined during the drilling agreed within 10 ft with those predicted by the seismic survey. The contour map of the buried bedrock surface shown on Figure 4 was prepared from the available seismic and well-log data.

In addition to the seismic study and test drilling, pumping tests were conducted at the original production wells, to determine optimum well spacing for the proposed additional wells, the safe yield of the glacial deposits, and water-level interference effects on neighboring well installations. These studies led to the successful completion of several new large-capacity wells in the deepest parts of the buried valley.

Even though buried valleys offer exceptional opportunities for ground-water development, certain problems may arise in the course of their exploitation. Locating the buried-valley aquifer may be only part of the solution to a particular water-supply problem. Of equal importance is the proper development of the ground-water reservoir. For example, pumpage that is highly con-

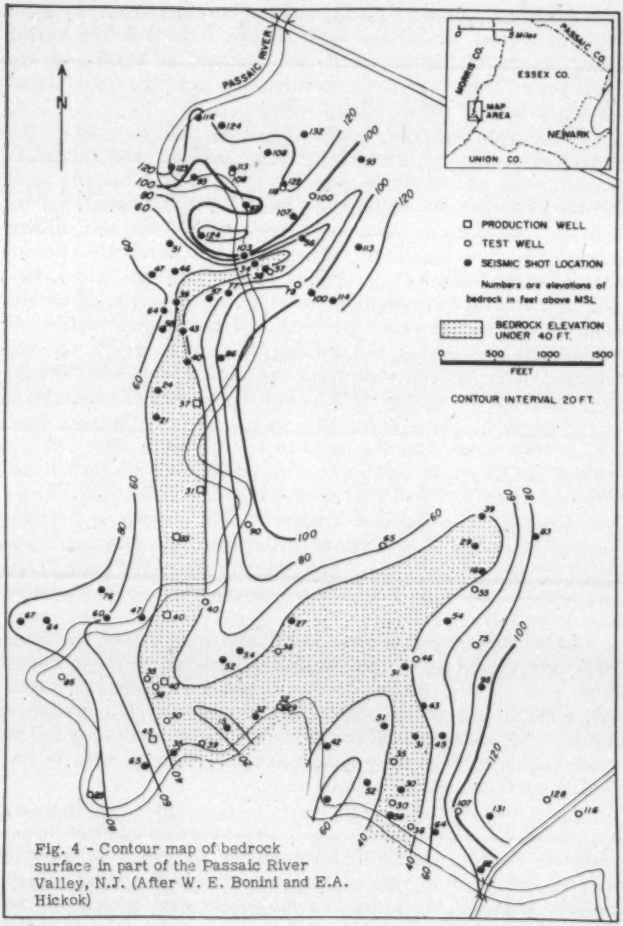


Fig. 4 - Contour map of bedrock surface in part of the Passaic River Valley, N.J. (After W. E. Bonini and E.A. Hickok)

centrated in a small area may produce severe water-level effects between wells. Furthermore, because the thickness and areal extent of the permeable sediments contained in a buried valley sometimes are limited, heavy pumping may lead to an eventual cut-back in yields. Therefore, it is always important to evaluate ahead of time through geologic reconnaissance, test drilling and test pumping the many factors which determine the water-supply potential of a buried-valley reservoir.

Buried-valley deposits located along existing water-courses may provide unusually large supplies of water if there is opportunity for ample infiltration from the surface stream. Rates of infiltration in such places depend on the relationship between stream stages and ground-water levels, and also on the water-transmitting characteristics of the materials bordering the stream. The latter feature is difficult to evaluate from an inspection of the surficial materials, and erroneous assumptions in this regard may prove costly when well facilities are constructed. Only careful analysis of pumping tests and observation-well data will give evidence as to the percentage of surface-water recharge under various pumping and water-level conditions.

Where an aquifer is overlain by thick beds of clay or till, downward percolation of rain water or induced infiltration from surface water may be greatly retarded, and special steps such as artificial recharge may have to be undertaken to guarantee a lasting ground-water supply. Artificial recharge has been effectively used in many buried-valley areas where ground-water storage is limited. For example, in Louisville, Ky., during World War II, some ground-water users recharged the buried-valley reservoir during the winter months with treated river water from public mains. By storing excess surface water underground during the winter, a supply of ground water was made available during the summer, when the flow in the nearby surface streams was too low to support water-supply requirements.

Even in areas where recharge is limited to precipitation and ground-water underflow, a buried-valley reservoir is still a very important resource. The amount of recharge gained from precipitation alone over a broad area can be substantial and, when combined with the ground water already in storage, may support large withdrawals from wells.

In conclusion, it should be emphasized that buried-valley deposits often provide a tremendous potential for water-supply development. Municipalities and industries contemplating expansion of their water systems or desirous of locating a new source of water supply should not overlook the possibility that such ground-water reservoirs may exist within the area of their interest and may be developed more economically than other sources of water. This possibility can often be established through a brief field study by hydrologists thoroughly familiar with geology and the principles of ground-water occurrence. The economic value of such studies can be readily appreciated from the numerous examples of large ground-water developments that continue to be made in buried-valley reservoirs.

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# ELECTROLYSIS AS IT AFFECTS THE WATER-WORKS SUPERINTENDENT

BY FRANCIS N. O'HARA*

[*Read September 16, 1958.*]

Corrosion has always been a source of annoyance to the water-works superintendent and has been present in this field since the inception of the delivery of water to communities for domestic and fire use.

Electrolysis has been recognized for a great number of years as the initiating action of corrosion, but only in the past 25 or 30 years have considerable study and research been given to it. Electrolysis sounds like, and is, an immensely big and technical subject, and it is the intent of this paper to take the technology out of it and present it as a common, everyday nuisance, such as the breakdown of equipment, gooseneck leaks, etc.

It is not the intent of this paper to belittle the scientific work put into the research on this subject, because without such results this paper could not be presented intelligently, and any conclusions drawn of necessity have to rely on these results of research for their proof.

Since inorganic chemistry is the basis of all corrosion and electrolysis, a brief introduction into the chemical background is necessary to understand completely the mechanics of corrosion and electrolysis. Chemical compounds are the results of the uniting of elements, such as the equation which follows:

$$2H_2 + O_2 = 2H_2O$$

where two molecules of gaseous hydrogen unite with one molecule of gaseous oxygen to form water. Other compounds are formed when one compound reacts with another compound, as in the following equation:

$$2H_2O + 2Na_2O_2 = O_2 + 4NaOH$$

The sodium peroxide reacts with the water, the sodium taking 4 OH or base radicals from the available hydrogen and oxygen

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in the chemicals to form four molecules of sodium hydroxide, and one molecule of oxygen going off as a gas.

Chemical equations are aided toward completion by energy in the form of motion, heat, light, pressure and electricity. All chemical compounds have an energy potential and, when put into solution, exert this potential to bring the resulting equation to completion. This is known as chemical energy, which is locked in every element and compound and may be given off as heat, light, motion, etc. Addition of another energy, such as electricity, even minute as it may seem, will increase the speed of completion of the equation.

As we are mainly concerned with water, water pipes, and water equipment, necessarily all corrosion and electrolysis have as their basis solutions. Solutions in inorganic chemistry are made up of four parts: acids, bases, salts and gases. Nearly all are soluble to some degree in water, and all conduct electricity when in solution with water, the degree depending on the ability of the acid, base or salt to conduct electricity. When an electric charge is added to the water, the positive and negative charges move toward opposite electrodes. Here they are liberated and either (1) escape from the solution as gases, (2) adhere to the electrode, (3) react with the electrodes, or (4) form new compounds. Example:

$$4\ Na^{+}Cl^{-} + 4H_2{}^{+}O^{-} + e = 4\ Na^{+}OH^{-} + 2H_2{}^{+}\uparrow + 2Cl_2{}^{-}\uparrow$$

At the positive pole chlorine is given off as a gas, and the sodium, attracted to the negative pole, reacts with the water, and hydrogen is given off as a gas; the sodium unites with the (OH) radical to form sodium hydroxide.

Where oxygen is present in the solution, it is attracted to the positive pole and there reacts with the electrode, and the resulting oxide is precipitated out of solution. Since almost every solution contains oxygen in one form or another, all are corrosive and subject to electrolysis in some degree.

So much for the chemical background. The next step logically is to explain the different methods by which electrical energy affects the steel or iron piping of our water systems.

In 1953 Eliassen and Lamb (1) have stated there are six kinds of cells or conditions that affect corrosion: (a) impressed

current, an example of which would be stray currents from street car tracks, or from similar sources; (b) galvanic, an example of which would be dissimilar metals in house services affected by stray currents from the ground or other sources; (c) differential-aeration or ease of accessibility of oxygen, an example of which would be corrosion of rivets in steel tanks; (d) concentration cells or difference in strength of solutions, an example of which would be a pipe line running through damp or wet ground, where the chemicals were more concentrated at one spot than the other; (e) differential temperature, not common in water works; (f) differential stress, not common in water works. Now any single piece of pipe can become two electrodes, just as a bar magnet has a north and south pole; by free access to oxygen one part becomes the cathode or negative pole and another part becomes the anode or positive pole. I shall refer to these by their second name—i.e., positive and negative poles. In the ionization of water the equation appears like this:

$$H_2O \rightleftharpoons 2H^+ + O^-$$

This equation continues ad infinitum unless something in the form of energy forces it to completion; an electrical charge will do this, the positive pole attracting the oxygen and the negative pole attracting the hydrogen. If the positive pole happens to be iron, it rapidly unites with the oxygen attracted to it and the entire positive pole decomposes or corrodes by electrolysis.

The conditions which affect water superintendents are as follows, and I shall take these in the order given for corrosion cells.

(a) *Impressed Current.* Electrical currents reach the pipe from many sources, such as return electricity from car tracks, grounding of heavy electrical equipment, etc. Such current travels along the pipe, forming a negative pole where it reaches the pipe, giving cathodic protection to that area of the pipe by the removal of hydrogen. It then travels to where it can again go back to its original course, or go to some source attractive to it. There the pipe becomes the positive pole, and iron from the pipe is lost by the action of electrolysis; that is, the oxygen with a negative charge is attracted to the positive pole and unites rapidly with the iron of the pipe. It has been proven that with a current of one ampere for one year, 20 pounds of material in the form of

iron can be removed from pipe. Large-diameter pipes attract electricity from smaller pipes in the networks surrounding them, because their capacity is greater. The results of impressed current usually appear as pitted areas on cast-iron pipe, before leaking and finally becoming a group of holes at the area affected. One such experience was encountered in Arlington in 1948; on a Friday night about 7:00 P.M. notification of a leak on Marathon St. was received by the Department. On investigating, the leak was near no service or fitting and was presumed to be a split pipe. Upon digging, five holes were found in an irregular pattern over about 3 sq in of the pipe, about 100 ft in from Massachusetts Ave., at a point near which the electrical system of the area went from an underground type to the pole type.

However, electrolysis was not presumed at this time to be the reason for the leak. One week later on Trowbridge St., one block east of Marathon St., a similar leak, though not as intense as the previous one, with similar circumstances was reported and, when dug, three small holes were found in an area covering about 1½ sq in. The electrical system conditions were the same as on Marathon St. This time electrolysis was suspected and the local carline notified. They immediately began a complete survey of the area along with the Edison Electric Co., but before it could be completed, a third leak was reported on Windsor St. under identical conditions with the previous two leaks.

On digging, one hole was found in the pipe. All conditions as to location from existing carlines, distance from Massachusetts Ave., and proximity to electrical systems going from underground to overhead were similar in all instances. The carline found a broken connection on the tracks on Massachusetts Ave. between Marathon and Cleveland Streets, which afforded the electricity an opportunity to jump to the water pipe and travel to the nearest point where it could jump off, which was Marathon St. at a point where the electrical system went from underground to overhead, approximately 100 ft from Massachusetts Ave.

The leak was repaired by cutting out a section of pipe and using two Dresser couplings with rubber gaskets not grounded, which prevented electricity from passing this point.

The electricity then proceeded to find a new outlet, which it did on Trowbridge St. and which was repaired in a similar man-

ner. Then the electricity had to find a new outlet, again finding a similar setup on Windsor St. The connection on the street-car tracks being repaired, no further leakage has been in evidence in this area caused by electrolysis, but the local gas company had to remove 200 ft of pipe destroyed by electrolysis across Massachusetts Ave. one year ago.

(b) *Galvanic*. This is probably the most common of all electric cells causing corrosion in smaller sizes of pipes, meters, and other water-works equipment. Dissimilar metals in the water-works field, such as brass shutoffs coupled to wrought-iron pipe, set up a galvanic cell, causing loss of metal to the lower of the two metals in the Electromotive force series, or galvanic series, which are given in Tables 1 and 2 and for all practical purposes are about the same. The EMF series remains the same under all conditions, but the galvanic series changes under different environments.

In the galvanic cell, a prime example is brass shutoffs at-

TABLE 1. ELECTROMOTIVE FORCE SERIES

| | |
|---|---|
| Calcium | Nickel |
| Sodium | Tin |
| Magnesium | Lead |
| Aluminum | Hydrogen |
| Zinc | Copper |
| Chromium | Silver |
| Iron | Platinum |

TABLE 2. GALVANIC SERIES

| | |
|---|---|
| (Corroded end) | Magnesium |
| Positive | Zinc |
| | Aluminum |
| | Steel or Iron |
| | Cast Iron |
| | Lead |
| | Tin |
| | Brass |
| | Copper |
| | Bronze |
| | Silver |
| | Gold |
| (Protected end) | Platinum |
| Negative | |

tached to iron pipe, where the iron is attacked and corroded and the brass valve remains intact. The brass valve is lower on the galvanic series and therefore becomes the negative pole of the cell, and the iron, the positive pole. Now, if we were to add zinc to the pipeline, the iron would be lower in the galvanic series and would become the negative pole, thereby gaining cathodic protection, and the zinc would become the positive pole and become corroded, saving the iron pipe.

(c) *Concentration cells* are another common type encountered in water works. Pipelines going through wet areas, where the concentrations of soluble chemicals vary widely, from one of the most common examples, and wells driven near the ocean, where the concentration of the salt varies at different levels. The section of pipe in the more concentrated solution becomes the negative and has cathodic protection, and the section in the less concentrated solution becomes the positive and corrosion results. Common places to find this are where pipelines are laid through abandoned ash dumps in wet areas, through salt marshes, and in swampy areas. Margaret St. in Arlington is an example of all these. Prior to the installation of locks on the Mystic River, the tide reached about ¾ of the area now occupied by Margaret St. After the tides no longer reached here, it became a wet, useless area and was utilized as an ash dump. Some years later the area was developed, mains were laid, houses built, and services installed. Corrosion of the concentration-cell type immediately started after installation; within a period of 15 to 20 years after the development, every service in the area and several sections of mains had to be relaid and surrounded by sand, 2 ft under, over, and on the sides of the mains and services. No further trouble has been experienced in the relaid areas. However, occasionally, leaks develop in the main that has not been touched. The gas line referred to in the paragraph on impressed current is also an example of a concentration cell. The pipe being laid in a wet, ashy area, corrosion was quite extensive, especially in the areas laid in the sandier mixture.

(d) *Differential aeration cells* are also common in the water works field, occurring where the metal is the same—i.e., iron—but the availability of oxygen to certain areas is less. The area receiving oxygen most rapidly becomes the negative and receives

cathodic protection, and the area that receives oxygen less rapidly becomes the positive and corrosion results. A prime example of this is the corrosion of rivets on a steel tank on the shank of the rivet, just under the head of the rivet; another is a partially covered pipe with some parts exposed. These are both external examples. An internal example would be two pieces of iron pipe coupled with an iron coupling. Every water works that has such connections must have experienced the latter.

(e & f) *Differential temperature* and *differential stress* cells are not found in water works, except as an aid to the foregoing cells in initiating the corrosion cell. These may be developed and tested in the laboratory, but join the overall picture in the field, and their effects are overrun by the more important effect of the aforementioned cells. Therefore, they can be eliminated from the water works field.

One example of *galvanic cell,* left out of the discussion of that cell purposely, is that of the electrolysis of meters. Herbert Barrett (2) has stated that galvanic corrosion has cost water works of the United States many millions of dollars, due not only to damage of meter, but even more to loss of revenue from stoppage of registration. The numbers of variations of combinations of metals forming galvanic cells in meters are almost countless, due to the fact that some bronze parts are cast, some made from drawn rod, and others from sheet, all having a different composition. Laboratory tests will not produce the answer to any particular problem, because it is not possible to simulate actual working conditions of each case, and the water used, although coming from the actual pipeline involved, either loses or gains corrosiveness as the case may be, due to contact with the air. Meter companies are aware of the problem and attempt every known method of combatting the problem, such as introducing monel into various parts to bring the metals closer together in similarity of composition, thus cutting down current flow between the metals and thus reducing corrosion. This does not always work in every type of water, especially in waters containing excessive chlorides, sulphates and $CO_2$. Another example of trying to combat electrolysis is to insert liners between the meter and the cast-iron bottoms in meters using them. The liners consist of plastic or brass, or the frost bottom may be coated with galvaneal or enams. Plastic has

proved most effective. In Arlington during the war, cast-iron frost bottoms were used of necessity, and every one, despite the fact they had copper liners, was attacked and eventually removed from service by electrolysis. The life of the meters was under five years. Velocity has an important part in the electrolysis of meters, and the trend of some departments is to enlarge their meters; naturally, the larger a meter, the larger is its measuring chamber and, therefore, a cutdown in velocity results.

Meter companies, I believe, should be made aware of any unusual conditions met in the field, and I further believe that any reputable company will follow the problem, if made aware of it, to its logical conclusion—i.e., introducing corrective methods of construction for the particular problem or looking further into the problem by experimentation.

## Methods of Control

Many methods of control are used. (1) *Connection to a high-potential ground,* such as street-car tracks or return line of electrical buses. Care must be observed that at periods of heavy use current doesn't pass backward to the pipeline. A current interrupter can prevent this, but protection is limited to the time the circuit is closed and current is flowing from the pipe.

(2) *Coating with inhibitors* both externally and internally, such as (a) painting surfaces with asphaltic paint, polyvinyl-chloride plastic, and galvanizing; (b) the introduction of metaphosphate glass into the waters that come in contact with the affected parts, thereby coating them with metaphosphate, a glossy, hard, practically impenetrable coating. In 1954, Lamb and Eliassen (3) said, "This glassy substance after continuous application gives negative protection besides positive protection and is called mixed inhibitor, but under practical conditions it is a negative inhibitor." Sodium metaphosphate has been used with such great results in preventing corrosion in Arlington on the Low Service that work has begun to put it into all the other services. Report of this was given by me in 1957 (4). (c) Introduction of $CaCO_3$ or any $CO_3$, to produce or to coat the pipe with a layer of $CaCO_3$, to prevent corrosion.

(3) *Sacrificial metals*—metals higher in the galvanic series introduced into the system, which eventually absorb all the cor-

rosive action, sparing the vital parts of the system. Examples of this are:—hanging magnesium rods in tanks to prevent electrolysis of the interior of the tank; zinc boxes placed on pipelines, where the water comes in contact with the zinc plates in the boxes, and they are sacrificed to protect the iron piping of the system; burying positive poles of metals higher in the galvanic series and connecting them to the object to be negatively protected by wires. This is called anodic protection.

(4) *Electrodeposition*—This is the result of negatively charged particles or ions forming a film on the positive pole, making the metal passive and actually changing its location in the electromotive-force and galvanic series. An example of this is passive stainless steel, which is similar to cast iron in the galvanic series when not treated with electrodeposition but, when treated, drops down to equal or below the bronzes. However, this film protection can be rubbed off by friction or scratched off, with the result that the effectiveness is completely reduced.

## Conclusions

(1) Iron pipe today, due to excessive use of DC current welding, street cars, and high pressure gas lines, is the greatest source of good ground conduction and necessarily becomes subject to electrolysis.

(2) The rate of corrosion is affected by many factors: (a) pH, (b) velocity, (c) temperature, (d) stress or pressure.

(a) and (b), pH rate of corrosion is the most important, since many noted consultants are using this as a basis of corrosion control. At high, or fairly high, velocities pH of 7.0 shows a higher rate of corrosion than 5.0 or 9.0, but at reduced values of velocity down to almost zero the same rate of corrosion is shown from 3.9 to 11.0 pH (5). (c) Temperature, which is always an important factor in any chemical equation, is more important in corrosion, because the higher the temperature, the higher the speed of ionization and the greater the electrical and chemical reaction. (d) Stress or pressure has a dual effect on reactions; sometimes pressure or stress tends to cut down electrolysis and chemical reaction; at other times it seems to accentuate and cause speed-up of electrolysis and chemical reaction.

Electrolysis is not new in water works, having been present

since water has been pumped, transported, and delivered by metal appurtenances. However, electrolysis due to impressed current is of greater importance today than ever, because of long high-pressure gas lines' picking up electricity and transferring to water pipes. This electricity has an affinity for larger pipes with greater conductivity. This is a highly technical subject, and the corrective methods for its reduction are debatable. Many leading consultants disagree on the various means of reducing this vital threat to large transmission mains. The water-works official should always be alert to his leakage, maintenance of equipment, and any part of the system showing corrosion, to see if electrolysis is the reason and, if so, to determine what type it is and apply the proper protective means at his disposal to reduce the electrolysis.

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# PROPOSED WATER-SUPPLY IMPROVEMENTS AND ADDITIONS TO THE NORTHERN EXTRA-HIGH SERVICE DISTRIBUTION SYSTEM OF THE METROPOLITAN DISTRICT COMMISSION

BY STEPHEN E. DORE, JR.†

[*Read September 16, 1958.*]

The Water Division of the Metropolitan District Commission of the Commonwealth of Massachusetts is responsible for collecting, storing, conveying and distributing water to the city of Boston and to many other metropolitan cities and towns. Because of the rapid post-war growth in population of the suburban areas adjacent to or within the geographical limits supplied by the Metropolitan District, the problem of proper and adequate distribution of water to these areas has continually confronted the District.

## *Description of Existing Water-Distribution Facilities*

The entire water supply for the Metropolitan District is obtained from watersheds in the western section of the Commonwealth and is conveyed through aqueducts to two distributing reservoirs located in the town of Weston. These reservoirs are the Norumbega Reservoir at Elev. 274.5* and the Weston Reservoir at Elev. 200. The Weston Reservoir supplies water through Low Service distribution mains to parts of Boston and to other metropolitan areas where this lower head provides adequate pressures. These Low Service mains are known as Supply Mains No. 1 and No. 2. The Norumbega Reservoir supplies water through the Hultman Aqueduct to the City Tunnel, which extends easterly through Newton to Shafts 7 and 7B near the Chestnut Hill Reservoir in Boston. Surface mains, connected to the Tunnel at Shaft 7B, distribute the water under this higher head to parts of Boston and to other metropolitan areas.

The Norumbega and Weston Reservoirs are shown on Figure 1 in the lower left-hand corner, and the City Tunnel ex-

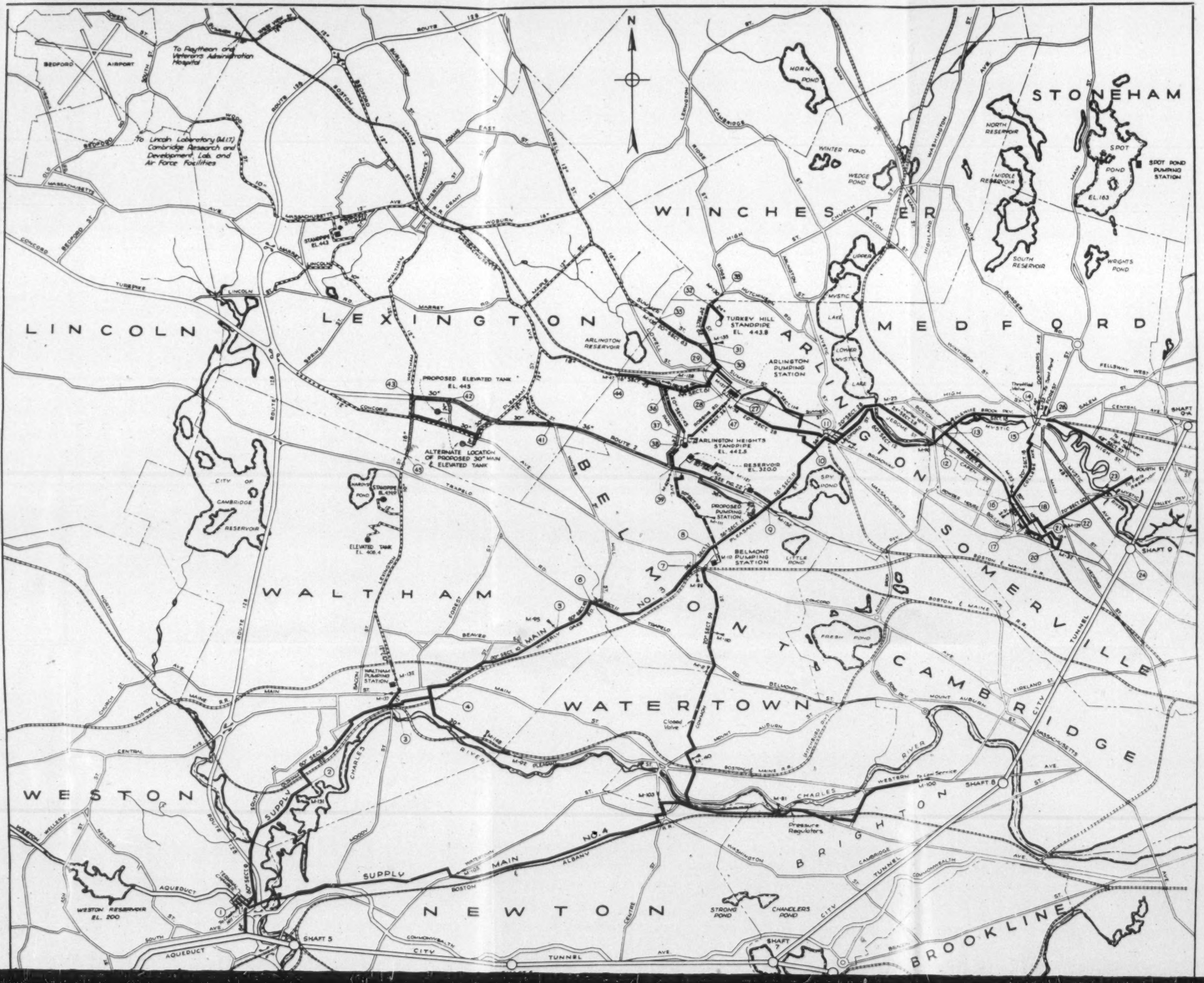
†Engineer, Coffin & Richardson, Inc., 68 Devonshire St., Boston, Mass.

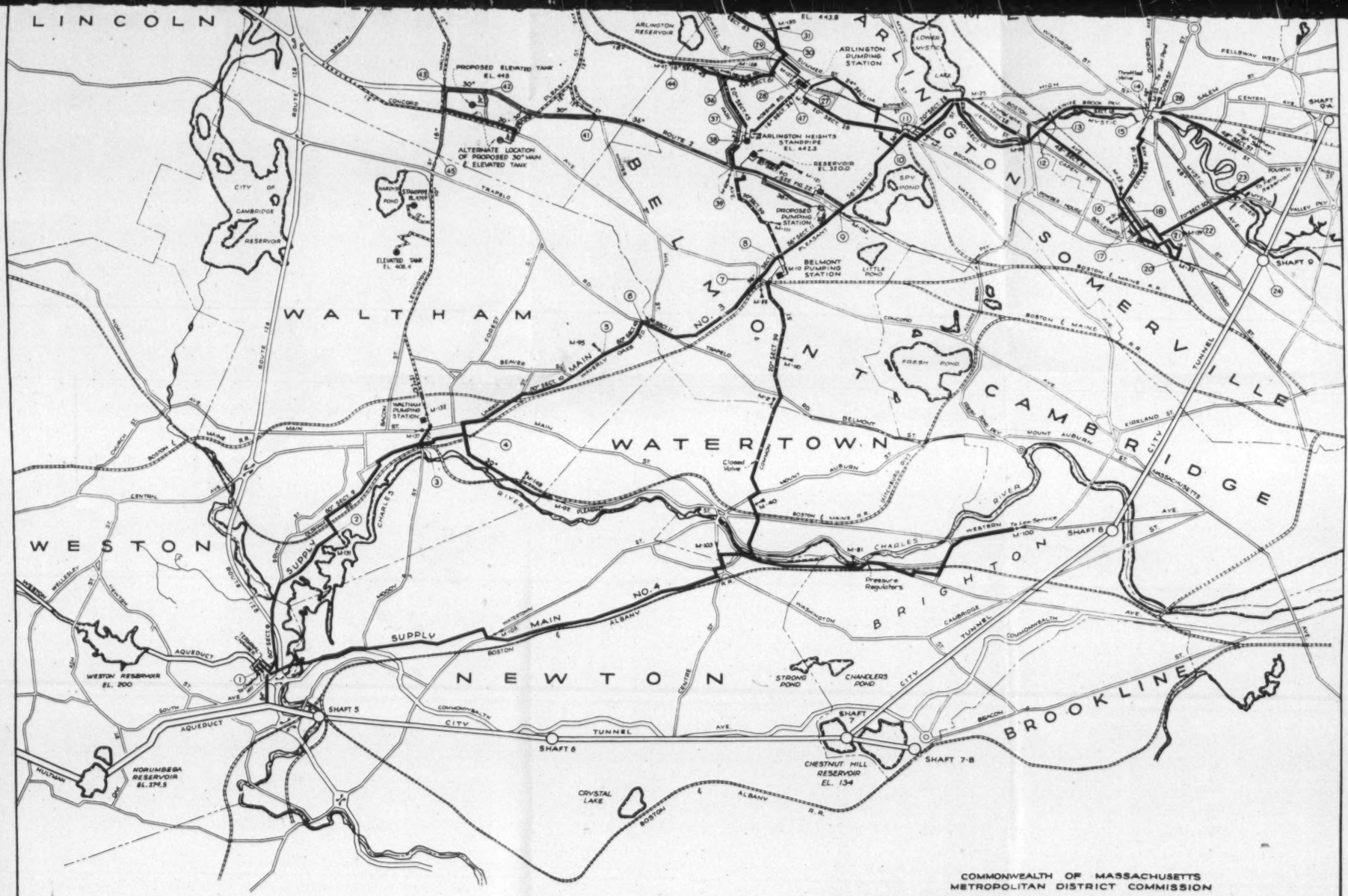
*This elevation and all subsequent elevations noted herein refer to the Boston City Base.

tending to Shafts 7 and 7B near Chestnut Hill Reservoir is shown along the bottom of the plan. At the present time, the City Tunnel is being extended in a northeasterly direction from Shaft 7 to Shaft 8 near Western Ave. and the Charles River in Brighton, to Shaft 9 near the Mystic River in Somerville, and to Shaft 9A near Central Ave. in Malden. The tunnel extensions and the new shafts are nearing completion, and the surface mains extending from these new shafts to the District's existing distribution networks in those areas are currently in the planning stage.

An 84-inch connection with the Hultman Aqueduct in Weston supplies water under Norumbega head to surface mains known as Supply Mains No. 3 and No. 4. Supply Main No. 4 is a 60-inch main which extends easterly to Boston and delivers water to portions of the city of Newton and Boston. At the easterly end of this supply main water is delivered to the District's Low Service mains through pressure regulators. Supply Main No. 3 is a 60-inch and 56-inch riveted steel water main and was installed in 1924 and 1925. This main extends from Weston northeasterly through Waltham, Belmont, Arlington and a part of Somerville and crosses the Mystic River into Medford, connecting with the District's Low Service distribution mains in Governors Ave. This supply main is approximately eleven miles in length and delivers water through numerous metered connections directly to the municipal distribution systems of Waltham, Watertown, Belmont, Arlington, Medford and Somerville. This main also supplies three of the District's water pumping stations, which provide the higher heads required for the areas of high ground elevations throughout this general area. These three pumping stations are located in Waltham, Belmont and Arlington.

The District's Waltham North Pumping Station, located on Lexington St., supplies Waltham's Lakeview High Service Distribution System, which serves the area of high elevation in the northern portion of that city. This station was constructed in 1951, and the pumping equipment consists of three centrifugal pumps, two of which are electric motor-driven and one is Diesel engine-driven. Supply for this station is obtained through a 12-inch, cast-iron suction main from Supply Main No. 3, and a relatively long, 12-inch cast-iron force main delivers water to the Lakeview High Service System. Distribution storage for this


STONEHAM
WINCHESTER
LINCOLN
LEXINGTON
ARLINGTON
MEDFORD
BELMONT
SOMERVILLE
WALTHAM
WATERTOWN
CAMBRIDGE
WESTON
NEWTON
BROOKLINE
To Raytheon and Veterans Administration Hospital
To Lincoln Laboratory (M.I.T.) Cambridge Research and Development Lab. and Air Force Facilities
BEDFORD AIRPORT
HORN POND
WINTER POND
WEDGE POND
NORTH RESERVOIR
MIDDLE RESERVOIR
SOUTH RESERVOIR
SPOT POND
SPOT POND PUMPING STATION
WRIGHTS POND
MYSTIC LAKE
LOWER MYSTIC LAKE
TURKEY HILL STANDPIPE EL. 443.8
ARLINGTON RESERVOIR
ARLINGTON PUMPING STATION
PROPOSED ELEVATED TANK EL. 445
ALTERNATE LOCATION OF PROPOSED 30" MAIN & ELEVATED TANK
ARLINGTON HEIGHTS STANDPIPE EL. 442.5
RESERVOIR EL. 320.0
SPY POND
PROPOSED PUMPING STATION
BELMONT PUMPING STATION
LITTLE POND
CITY OF CAMBRIDGE RESERVOIR
STANDPIPE EL. 490.0
ELEVATED TANK EL. 408.4
FRESH POND
WALTHAM PUMPING STATION
CLOSED VALVE
PRESSURE REGULATORS
WESTON RESERVOIR EL. 200
STRONG POND
CHANDLERS POND
SHAFT 5
SHAFT 7
SHAFT 8
SHAFT 9
SHAFT 9A
NO. 3 MAIN
NO. 4 MAIN
WESTON SUPPLY AQUEDUCT
BOSTON & ALBANY SUPPLY MAIN
COMMONWEALTH AVE TUNNEL
BRIGHTON TUNNEL
CHARLES RIVER
N




LEGEND

- Existing High Service Supply Mains
- Existing Intermediate High Service Mains
- Existing Northern Extra High Service Mains
- Proposed Extensions and Additions to the Existing Systems
- City and Town Water Distribution Systems
- Existing M.D.C. Metered Connections
- Proposed M.D.C. Metered Connections
- Pipe Intersections and Demand Points

COMMONWEALTH OF MASSACHUSETTS
METROPOLITAN DISTRICT COMMISSION

SUPPLY MAIN NO. 3 AND NORTHERN EXTRA HIGH SERVICES

# GENERAL PLAN OF EXISTING SYSTEMS AND PROPOSED IMPROVEMENTS AND ADDITIONS

COFFIN & RICHARDSON, INC. - ENGINEERS
BOSTON, MASS.

SCALE

JULY, 1957

Fig. 1

C&R Acc. 877

system is provided by a steel standpipe, located near Hardy Pond. This standpipe was erected in 1956 and has a capacity of 1 mil gal and an overflow elevation of 434.9.

The Metropolitan Pumping Station in Belmont takes water from Supply Main No. 3 through a 20-inch cast-iron suction main and pumps through a 20-inch cast-iron discharge main to the District's covered reservoir in Arlington. This reservoir has a capacity of 2 mil gal and an overflow elevation of 320.0. This system is designated as the Intermediate High Service System and supplies sections of Arlington, Belmont and Watertown through metered connections directly to each municipal distribution system. The Belmont Pumping Station was constructed in 1937, and the pumping equipment consists of three electric motor-driven, centrifugal pumps, two of which are operated automatically by the change in water level of the Arlington covered reservoir. The third pump is manually operated during periods of high demand.

The Metropolitan Pumping Station located on Brattle Court in Arlington takes water from Supply Main No. 3 through two suction mains, a 20-inch cast-iron main installed in 1899, and a 24-inch reinforced-concrete main installed in 1944. This pumping station was constructed in 1907 and presently contains three variable-speed, Diesel engine-driven pumping units and one constant-speed, electric motor-driven pumping unit. These units pump into the District's Northern Extra-High Service System, which consists of several distribution mains varying from 16 to 24 inches in diameter and two distribution storage standpipes, all located within the town of Arlington. This Extra-High Service System although located in Arlington, supplies the entire water requirements of the town of Lexington through two metered connections to the Lexington distribution system. These metered connections are located on Summer St. and on Massachusetts Ave. at the Arlington-Lexington town line. This Extra-High System also supplies those areas of Arlington, Belmont and Winchester, which require this higher service, through metered connections to each municipal distribution system. Distribution storage for this Extra-High Service is provided by two standpipes. The Arlington Heights Standpipe, located near the Belmont-Arlington town line, was erected in 1922 and has an over-

flow elevation of 442.5. This tank is 75 ft in diameter and has a capacity of 2.0 mil gal. The Turkey Hill Standpipe, located near the Arlington-Winchester town line, was erected in 1945 and has an overflow elevation of 443.8, or 1.3 ft higher than the Arlington Heights Standpipe. This tank is also 75 ft in diameter and has a capacity of 2.0 mil gal.

In addition to supplying the numerous metered connections and the three District pumping stations, Supply Main No. 3 delivers water through a throttled valve at Governors Ave. in Medford to the Low Service water mains supplying the District's Spot Pond facilities in Stoneham and also through pressure regulators to parts of Arlington and Medford.

In March, 1957, Coffin & Richardson, Inc., Consulting Engineers, of Boston, Mass., was engaged by the Water Division of the Metropolitan District Commission to make detailed hydraulic investigations of Supply Main No. 3 and of the distribution and pumping facilities of the Northern Extra-High Service System, to determine the need for improvements to these facilities.

For the past several years, both Supply Main No. 3 and the Northern Extra-High Service System have been experiencing greater difficulty in supplying the water demands of the areas served, particularly during extended periods of hot weather. The large flows required in Supply Main No. 3 create high friction losses, which result in a substantially lowered hydraulic gradient in this supply main, and the facilities of the Northern Extra-High Service System are limited both in pumping and distribution storage capacity, with the result that pressures are reduced during periods of peak demands in this system.

With the completion of the City Tunnel to the new Shafts 8, 9 and 9A, together with the proposed surface connections from these shafts to the District's existing distribution network in these areas, Supply Main No. 3 will not be required to carry the large flow presently being carried for the Spot Pond facilities. This flow will be delivered through the new surface connections from the extended City Tunnel.

*Population and Water Consumption*

To determine the present and future water demands upon Supply Main No. 3 and the Northern Extra-High Service Dis-

tribution System, detailed studies were made to determine the present and the estimated future requirements of each city and town served by these facilities.

Records of growth in population were tabulated from census reports, and plans of each city and town were obtained, showing the available land areas and the present zoning regulations. Each municipality was then studied relative to its past growth, remaining land area available for expansion under present zoning regulations, and its individual potential for growth. Officials of all of the municipalities concerned were consulted in reference to both the present plans for land development and any contemplated or possible future plans or zoning reclassifications. From these studies and consultations, estimates were made of the future populations for each city and town for the years 1960, 1980 and 2010.

Arlington, Medford, Somerville and Watertown are fairly well developed municipalities with relatively small areas remaining for expansion and, therefore, could only be expected to grow at a comparatively slow rate. However, parts of Belmont, Lexington, Waltham and Winchester contain relatively large areas where considerable future growth could be expected. The areas in Belmont, Lexington and Winchester, where land is available and the potential for growth is great, are those areas which require water from the Northern Extra-High Service System. In Waltham, the area of greatest future growth is the area supplied by the Lakeview High Service System.

Table 1 shows the recorded 1955 population and the estimated future population for the years 1960, 1980 and 2010 for each city and town served from Supply Main No. 3. For the town of Arlington, the 1955 population was 47,148, and it was estimated that the population in the year 2010 will be approximately 52,000. Belmont's population was estimated to increase from 28,790 to 37,000, with the greatest portion of this increase occurring in the areas requiring Northern Extra-High Service water. Lexington has large areas of land available for development, and it was estimated that the population of this town will increase from 22,256 to 60,000. Medford, Somerville and Watertown all have relatively few areas remaining for development, and therefore small increases in populations were estimated for

these municipalities. The population of Waltham was estimated to increase from 50,115 to 72,800, and a large portion of this increase will require Lakeview High Service water. Winchester is partially supplied by the Northern Extra-High Service System, and the population figures shown for 1955 and the estimated future population are only for the area served and not for the entire town.

TABLE 1.—TOTAL POPULATION OF MUNICIPALITIES SERVED FROM SUPPLY MAIN NO. 3

| | Actual population 1955 | Estimated population 1960 | 1980 | 2010 |
|---|---|---|---|---|
| Arlington | 47,148 | 47,500 | 49,500 | 52,000 |
| Belmont | 28,790 | 31,000 | 35,900 | 37,000 |
| Lexington | 22,256 | 29,000 | 50,000 | 60,000 |
| Medford | 65,393 | 66,200 | 70,000 | 75,000 |
| Somerville | 97,032 | 98,000 | 100,600 | 105,000 |
| Waltham | 50,115 | 52,500 | 61,600 | 72,800 |
| Watertown | 38,898 | 39,400 | 42,000 | 45,000 |
| Winchester | 2,426(a) | 3,200(a) | 5,500(a) | 6,500(a) |

(a) Population of area supplied from M.D.C. only.

To determine the water-supply requirements of these municipalities, the District's meter records were obtained and studied for all of the meters served from Supply Main No. 3.

Table 2 shows the actual 1955 and the estimated future average daily water requirements for the areas served from Supply Main No. 3. These requirements are listed by meter number and location and are in mgd. A total of fourteen metered connections which are served directly from Supply Main No. 3 required an average of 13.27 mgd in 1955. It was estimated that the future average daily use through these meters will increase to approximately 17.50 mil gal by the year 2010. The Waltham North Pumping Station pumped an average of 0.403 mgd in 1955, and it was estimated that the Lakeview High Service area in Waltham will require 2.21 mgd in the year 2010. Due to limitations of the suction and discharge facilities of this pumping station, the maximum average daily pumping rate from this station was determined to be aproximately 0.65 mil gal. It will be explained

TABLE 2.—PRESENT AND ESTIMATED FUTURE AVERAGE DAILY WATER REQUIREMENTS THROUGH SUPPLY MAIN NO. 3

| M.D.C. meter no. | City or town | Million gallons per day 1955 | 1960 | 1980 | 2010 |
|---|---|---|---|---|---|
| | *To Metered Connections* | | | | |
| 152 | Arlington | 0.7435 | 0.87 | 0.94 | 1.02 |
| 1 | Arlington | 0.9037 | 1.06 | 1.14 | 1.25 |
| 88 | Belmont | 0.6723 | 0.71 | 0.78 | 0.83 |
| 25 | Medford | 1.2660 | 1.40 | 1.57 | 1.85 |
| 23 | Medford | 0.4265 | 0.47 | 0.53 | 0.62 |
| 22 | Medford | 0.7947 | 0.88 | 0.99 | 1.16 |
| 129 | Medford | 0.2511 | 0.28 | 0.31 | 0.37 |
| 31 | Somerville | 0.6406 | 0.63 | 0.68 | 0.75 |
| 32 | Somerville | 1.6531 | 1.63 | 1.76 | 1.94 |
| 131 | Waltham | 2.3431 | 2.41 | 2.61 | 2.85 |
| 137 | Waltham | 1.4670 | 1.54 | 1.74 | 2.02 |
| 148 | Waltham | 1.0705 | 1.15 | 1.34 | 1.62 |
| 95 | Waltham | 0.6975 | 0.75 | 0.75 | 0.75 |
| 92 | Watertown | 0.3392 | 0.37 | 0.42 | 0.48 |
| Total metered connections | | 13.2688 | 14.15 | 15.56 | 17.51 |
| | *To Waltham North Pumping Station Waltham's Lakeview Service* | | | | |
| 132 | Waltham | 0.4027 | 0.65 | 0.65 | 0.65 |
| | *To Belmont Pumping Station Intermediate High Service* | | | | |
| 121 | Arlington | 0.2099 | 0.25 | 0.27 | 0.29 |
| 111 | Belmont | 0.0589 | 0.10 | 0.17 | 0.22 |
| 110 | Belmont | 0.9667 | 0.98 | 1.01 | 1.04 |
| 2 | Watertown | 0.2542 | 0.28 | 0.31 | 0.36 |
| Total I.H.S.S. | | 1.4897 | 1.61 | 1.76 | 1.91 |
| Total N.E.H.S.S. (See Table 3) | | 4.8752 | 7.05 | 11.02 | 14.03 |
| | *To Low Service through Throttled Valves* | | | | |
| Jerome St., Medford | | 7.1961 | 0.00 | 0.00 | 0.00 |
| Governors Ave., Medford | | 18.0 | 0.00 | 0.00 | 0.00 |
| Total throttled valves | | 25.1961 | 0.00 | 0.00 | 0.00 |
| Total through Supply Main No. 3 | | 45.2325 | 23.46 | 28.99 | 34.10 |

shortly where the remaining 1.56 mil gal will be obtained, to supply the estimated future requirements of this service.

A total of four meters in the District's Intermediate High Service Distribution System recorded an average daily use of 1.49 mil gal in 1955, and it was estimated that the future average daily requirements of the areas supplied by these meters will increase to 1.91 mil gal in 2010.

The meters in the Northern Extra-High Service System recorded an average daily use of 4.87 mil gal in 1955, and it was estimated that the future average daily requirements for this system will increase to 14.03 mil gal in 2010. These requirements in the Northern Extra-High Service System, subdivided by meter locations, are shown in Table 3.

TABLE 3.—AVERAGE DAILY WATER CONSUMPTION OF NORTHERN EXTRA-HIGH SERVICE SYSTEM

| | Million gallons per day | | | |
|---|---|---|---|---|
| | Actual | Estimated | | |
| | 1955 | 1960 | 1980 | 2010 |
| *Arlington* | | | | |
| Total — Meter Nos. 86, 128 and 135 | 1.5431 | 1.82 | 1.95 | 2.14 |
| *Belmont* | | | | |
| Meter No. 62 | 0.2934 | 0.51 | 0.94 | 1.21 |
| *Lexington* | | | | |
| Total — Meter Nos. 47 and 136 | 2.6771 | 4.40 | 6.90 | 8.40 |
| *Winchester* | | | | |
| Meter No. 130 | 0.3616 | 0.32 | 0.57 | 0.72 |
| Total N.E.H.S. | 4.8752 | 7.05 | 10.36 | 12.47 |
| *Waltham* | | | | |
| Proposed Meter | 0.00 | 0.00 | 0.66 | 1.56 |
| Total N.E.H.S. and Waltham | 4.8752 | 7.05 | 11.02 | 14.03 |

From the records of several line meters throughout the District's system, it was determined that the average daily flows through the throttled valves to the Low Service mains totaled 25.2 mil gal. The large flows presently delivered through these throttled valves will, in the future, be supplied by the extended

City Tunnel and its surface connections. Consequently, the future requirements through these valves from Supply Main No. 3 are shown in the table as zero.

Thus, for 1955, the total average daily flow through Supply Main No. 3 was determined to be 45.23 mil gal. It was estimated that the total flow through this main will decrease to 23.46 mgd with the completion of the City Tunnel extensions in about 1960, increasing to approximately 29 mgd in 1980 and to 34 mgd in 2010.

Table 3 shows the 1955 average daily water consumption and the estimated future consumption at all meters supplied by the Northern Extra-High Service Distribution System. These water requirements are tabulated by location and meter number, and the quantities are shown in mgd. It was estimated that the average daily requirements of the areas supplied by the three meters in Arlington will increase from the actual 1955 use of 1.54 mgd to 2.14 mgd in 2010, and the requirements of the area served by the single meter to Belmont will increase from 0.29 mgd to 1.21 mgd. In Lexington, it was estimated that the 1955 requirements of 2.68 mgd will increase to 8.40 mgd, and in Winchester, the requirements will increase from 0.36 to 0.72 mgd in 2010.

Thus, it was estimated that the total average daily water requirements of the Northern Extra-High Service System will increase from 4.87 mgd in 1955 to 12.47 mgd in 2010.

Since the Lakeview High Service area in Waltham is presently supplied at a slightly lower head (434.9) than is provided in the Northern Extra-High Service System, it would be practicable to supply the Lakeview High Service area from the Northern Extra-High Service through pressure regulators, if the distribution mains of this system were extended closer to the Lakeview area. Since the proposed improvements resulting from these investigations recommend extension of the System closer to this area, the future requirements of the Lakeview High Service area were proposed to be supplied from the Northern Extra-High Service System, making a total of 14.03 mgd to be served by this System in 2010.

In addition to the average daily water requirements, studies were made of the meter records, to determine the peak flow requirements of these municipalities. Many of the District's meters

are of the chart-recording type, which give a continuous record of the flow through the meter; however, several of the meters do not record but merely totalize the flow. For these meters, weekly readings were available, and it was necessary to estimate the peak flows at these locations. From these meter charts and records, and the records of water level in the two storage standpipes of the Northern Extra-High Service System, the maximum daily requirements of the system were determined and peak flows estimated.

These studies showed that for these eight municipalities the average daily consumption during the week of maximum consumption was approximately 1.5 times the average daily consumption, and that the maximum daily consumption was approximately twice the average daily consumption.

If these determined ratios are used, the future maximum daily consumption for the area served by the Northern Extra-High Service System will approximate 11 mil gal in 1960, 14 mil gal in 1980, and 28 mil gal in 2010.

*Flow Analyses*

Based on the 1955 requirements and the estimated future, average and maximum daily requirements, as determined for each meter served by Supply Main No. 3 and the distribution system of the Northern Extra-High Service System, several flow analyses were made to determine the quantity of flow and the head loss in each section of the systems. The flow analyses were made by means of the McIlroy Pipeline Network Analyzer at Cornell University in Ithaca, N. Y. The operation of the analyzer was performed by Mrs. Malcom McIlroy of Cornell University at the direction of, and assisted by, engineers of Coffin & Richardson, Inc. All necessary data for the use of this electrical analyzer were obtained from the records of the Water Division and correlated prior to work at the university.

Several analyses were made for various conditions of present and proposed future methods of supply, utilizing both the present and the estimated future demands on both the Northern Extra-High Service System and Supply Main No. 3.

From these flow analyses and other hydraulic investigations of these systems, the following conclusions were clearly demonstrated:

1. The large flows presently required in Supply Main No. 3 create high head losses in various sections of this main. These high losses result in a greatly reduced hydraulic grade line, which adversely affects the pumping ability of the District's pumping stations, particularly the Arlington Pumping Station. However, with the completion of the City Tunnel, this condition will be greatly improved, due to the reduction of the flow in Supply Main No. 3.

2. The existing distribution system of the Northern Extra-High Service requires extensive reinforcement, in order to provide the present peak flows and the estimated future requirements of the towns of Lexington and Belmont.

3. The existing pumping station in Arlington has neither the required pumping capacity nor properly sized suction and discharge mains to deliver either the present peak flow requirements or the future water requirements of the Northern Extra-High Service System.

4. The existing storage facilities of the Northern Extra-High Service System cannot provide sufficient quantities for peak flow requirements without a substantial loss in pressure throughout this system.

5. The District's pumping station in Waltham cannot provide the estimated future requirements of the Lakeview High Service area.

*Proposed Improvements and Additions*

To correct these existing deficiencies in the systems and to provide for the future water-supply requirements of the areas served by them, the following improvements were proposed:

The construction of a new pumping station was recommended, which would take suction from Supply Main No. 3 and pump to the Northern Extra-High Service Distribution System, supplementing the existing pumping facilities in Arlington. The location of this new station was proposed adjacent to Route 2 near Pleasant St., because of certain hydraulic advantages of this general area. This location requires a relatively short suction main from Supply Main No. 3, and the discharge main can extend directly west along Route 2 and connect with the existing distribution main at Park Ave. Future extension of the Northern

Extra-High Service System can continue westerly along Route 2 into the town of Lexington. Such a route would deliver water directly to the town of Lexington and to the areas of Belmont and Waltham where the greater proportion of the future growth will occur.

The proposed pumping station is shown on the plan adjacent to Route 2, approximately 1,000 ft west of Pleasant St. A 36-inch suction main for this station was proposed from Supply Main No. 3 in Pleasant St., and a 36-inch discharge main approximately 4,700 ft in length was proposed, extending westerly from the pumping-station site along Route 2 and connecting with the existing distribution main of the Northern Extra-High Service in Park Ave.

It was also proposed that the 36-inch discharge main be extended from Park Ave. westerly along Route 2 to Watertown St., Lexington, a distance of approximately 6,800 ft. From this point, a 30-inch main was proposed westerly along Route 2, terminating at Waltham St., a distance of approximately 7,600 ft. Two additional metered connections to the Lexington distribution system were proposed at Watertown St. and Waltham St. A new 16-inch main was proposed from the intersection of Route 2 and Waltham St., extending approximately 3,200 ft southerly in Waltham St. and connecting with the existing Lakeview High Service distribution system in Waltham near the Waltham-Lexington town line. A pressure regulator and meter station were proposed at this location.

In addition to these mains proposed in new locations, a 24-inch main approximately 5,400 ft in length was recommended to be installed in parallel with the existing 20-inch and 12-inch main in Park Ave. between Paul Revere Rd. and Route 2. This reinforcing main is required to reduce the high head losses in this section of the distribution system.

In addition to the proposed pumping station and water mains, additional storage capacity was recommended for the Northern Extra-High Service System, to supplement the limited capacities of the Arlington Heights and the Turkey Hill Standpipes. An elevated water-storage tank, having a capacity of 2.0 mil gal and an overflow elevation of approximately 445, was recommended to be located near the extremity of the proposed 30-

inch main in Route 2 at Waltham St. Two possible sites for this proposed elevated tank are in Lexington on the high ground south of Route 2 just east of Waltham St., or south of Concord Ave. just west of Pleasant St. If the latter site is finally selected, a slightly different route for the 30-inch main previously described along Route 2 would be required between Pleasant St. and Waltham St. in Lexington.

These several improvements were recommended for construction in two phases. The first phase recommended the immediate construction of the proposed pumping station, together with its suction main and its discharge main connecting with the existing distribution system at Park Ave. and Route 2, and also the construction of the 24-inch reinforcing main in Park Ave. from Route 2 to the Arlington Heights Standpipe.

The second phase included the installation of all other mains proposed for this system and the erection of the additional storage facilities. This phase was recommended for completion by 1963.

At the present time, contract plans and specifications are being prepared for the construction recommended in Phase I. Bids for furnishing and delivering equipment have been received, and orders have been placed for the water piping and valving, and the mechanical, electrical and hydraulic equipment to be installed in the pumping station.

The pumping equipment consists of four electrically-driven centrifugal pumping units. One unit will deliver approximately 3 mgd, and the remaining three units will each deliver approximately 6 mgd. The combined pumping capacity of these units operating in parallel will be approximately 19 mgd. The total horsepower requirements for these four units are 1,050. Two of the higher-capacity pumps will have auxiliary Diesel engines for use in event of electric power failure. Operation of the pumping units will be automatically controlled by the water level in the Turkey Hill Standpipe or by manual control at the station. Since it is contemplated that this station will normally be unattended, provisions for remote operation of the pumping units are to be installed in the existing Arlington Pumping Station, which is constantly attended under present operating conditions.

The pumping-station building will consist of two areas, a utility area and a pumping area. The utility area will contain an

office, toilet, heater room and small shop area. The pump-room area will be four feet lower in elevation than the utility area and will house the four pumping units, the electrical switchgear, and the hydraulic instrumentation and control center. A unit substation, to transform the power supply from the Boston Edison Co., will be located near the building within a fenced area.

The building will have a structural steel frame and will be supported by concrete foundation walls and footings, bearing on ledge. The sidewalls will be constructed of coursed ashlar granite with granite trim on the exterior and will be clear glazed structural and acoustical tile on the interior. The ceiling will be a suspended acoustical tile ceiling, and the floor surfaces in both the pump room and utility area will be of reinforced concrete, finished with red quarry tile. The roof will be a flat, concrete slab roof with a rigid insulation, imbedded on a 2-ply vapor seal and covered with a 4-ply tar-and-gravel roof. It is anticipated that construction of the pumping-station building and the installation of the equipment will commence in the late fall and be completed during the coming year.

# INVESTIGATION OF LIQUID-ALUM FLOW MEASUREMENT

BY KENNETH F. KNOWLTON* AND RUSSELL H. BABCOCK†

[*Read September 17, 1958.*]

The use of liquid alum as a coagulant in water supply has become widespread over the last few years because of its availability, cost, and ease of handling. These are facts which make its use economically desirable. The Salem and Beverly Water Supply Board, recognizing these facts, made an installation for feeding liquid alum in January, 1955.

In 1954, dry alum cost, delivered at the filters, $39.40 per ton. Liquid alum delivered at the plant was $34.00 per ton of dry-alum equivalent. At an average yearly consumption of 300 tons this represented a saving of $1,620 per year.

Prior to the change-over at Salem and Beverly, considerable thought was given to the equipment for the control of this material. The equipment installed was a pH recorder-controller, which adjusted a pneumatically operated valve on the alum-flow line. After going through the control valve, the alum syrup was mixed with water in a plastic injector and discharged into the raw-water pipe preceding the mixing basins.

This system gave what was thought to be good control. However, at about this same time the authors had also been working with conductivity-difference control of fluoride addition to water and subsequently adapted this equipment to the control of liquid alum. This conductivity equipment was used for about two years, and this installation proved more satisfactory than pH control.

During the extensive work done with both pH and conductivity difference, we became more acutely aware of some of the mechanism of coagulation with alum. During the winter months in particular, we were able to produce good water with less alum by achieving close control of the alum dose, coupled with the fact that the alum was in solution before being applied. Table 1 shows these data.

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†Manager, Water and Waste Division, The Foxboro Co., Foxborough, Mass.

The raw water at this installation is rather uniform in its characteristics, and while some type of control was necessary for the feeding of the alum, we felt it could be of a simpler variety than the two types previously utilized. Because of this fact, it was decided to investigate the possibilities of the actual flow measurement of liquid alum on a volumetric basis. The success of such a measurement would make the ratioing of liquid alum to plant flow a simple matter.

TABLE 1.—COMPARISON OF QUANTITIES OF DRY ALUM AND LIQUID ALUM REQUIRED FOR COAGULATION

| | Alum consumption (lb per mil gal) | |
|---|---|---|
| | Jan., Feb., and Mar. | Year |
| Dry Alum | | |
| 1952 | 304 | 235 |
| 1953 | 276 | 217 |
| 1954 | 305 | 242 |
| Liquid Alum | | |
| 1955 | 251 | 206 |
| 1956 | 180 | 170 |
| 1957 | 181 | 188 |
| 1958 | 189 | 182 |

The obvious approach to this matter was to use a rotameter. However, experience gained by the city of Chicago indicated that there were potential problems, due to the development of a layer of crystalline material on the inside of the tube and around the rotor. Where transmission was used, difficulty was also experienced with the same crystalline material accumulating between the tail rod on the rotor and the body of the meter. In addition to this, the crystalline accumulation occurred in the needle valve at the point of control. Diluting the alum with water appeared to aggravate both of these problems. Apparently, liquid alum tends to bind mechanical parts of a device, such as a rotameter, which must move with a limited amount of power applied. Also, if it is desired to record, control or ratio the flow by means of a rotameter, the auxiliary equipment needed is very expensive.

For the above reasons, an Integral Orifice d/p Cell Transmitter, manufactured by The Foxboro Company, was installed to measure alum-syrup flow. Our previous installations had not in-

cluded any measuring device on the alum flow, except for a short period when a plain rotameter was used for some calibration studies.

To be really useful, any measuring device should be capable of easily transmitting the reading to any desired point in the plant and of using this same reading to control the feed of alum. The Integral Orifice d/p Cell Transmitter described in this paper

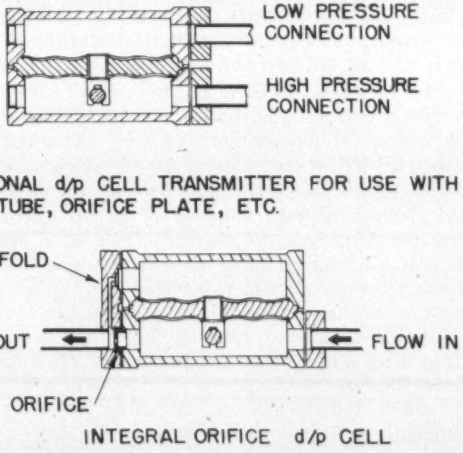


FIG. 1.—SECTIONAL DRAWINGS OF d/p CELL TRANSMITTER AND INTEGRAL ORIFICE d/p CELL TRANSMITTER.

has these characteristics. This device is, essentially, a conventional force-balance pneumatic transmitter, except that pressure taps are not taken off the conventional primary device. Instead, a small orifice is installed as part of the transmitter. The flow then passes directly through the transmitter, the differential pressure being measured and turned into a pneumatic signal in the conventional manner (Fig. 1).

Since orifices are available for this device from ¼ in. in size down to 0.020 in. in diameter, a wide range of liquid-alum flows can be handled with the device. Also, the transmitter is capable

of adjustment from a full range of 20 in. to 250 in. of water. For example, the transmitter presently in service is equipped with an orifice with a bore of 0.0995 inch. Maximum range is 250 gal per day or 0.17 gal per min. The Integral Orifice d/p Cell Transmitter is capable of measuring accurately 25% of this value. A lower flow range could be achieved by merely substituting a smaller orifice, or vice versa.

The Integral Orifice d/p Cell Transmitter has been used by industry for several years for water, air, and hydrocarbon flow measurement. The output of the instrument is an air signal, varying from 3 psi to 15 psi in proportion to the square of the flow.

In our studies at Salem and Beverly we have used a standard receiver with a chart graduated from 0-100 and devised calibration curves for different orifices and differential ranges. This method allows for the broadest use of the equipment.

So far, we have used the device only for measuring the alum flow. Control has been achieved by the pH instrument, the conductivity instrument, or manually. We have been particularly concerned with determining whether or not the instrument would have a tendency to plug or develop coatings or deposits which would impair its operation. During six months of operation there has been no evidence of plugging, and the measurement has been stable. This is in contrast to the reported experience at Chicago, where difficulty was experienced with plugging of transmitting rotameters. With a straight indicating rotameter, used over a two-month period, we experienced no difficulty.

The alum purchased is filtered and adjusted by the supplier to a uniform $Al_2O_3$ content of 8% (commercial paper-making grade). The supplier's truckman pumps it directly to a lead-lined storage tank, from which it is fed by gravity without dilution. This fact may account for the lack of difficulty in our equipment.

In three years of operation, only one plugging has occurred in the portion of the equipment handling undiluted alum. On this one occasion a piece of foreign matter plugged the small opening in the pneumatic valve.

In contrast, the portion of the system where the alum is diluted for addition to the raw water requires periodic cleaning, starting with the injector itself, where the alum and water first

meet. This cleaning, however, is only necessary about four or five times a year.

In the control of liquid alum through a small valve, it seems to be necessary to use some method which will keep the valve "alive." This factor eliminates the use of a simple control method, where the valve position is set directly from the ratio of flow of water through the plant. In this case, small accumulations of sediment might gather in the valve, thus reducing the alum feed. Also, it gives the valve stem a chance to stick in the packing.

Whether pH, conductivity difference, or a ratio controller between alum flow and water flow is used, any irregularity in the flow of the alum will move the valve. Small deposits in the valve are, therefore, automatically flushed through. If the valve stem should tend to stick, the air pressure would gradually build up until the stem was freed. With a flow recorder on the alum feed, valve restriction or sticking beyond a minor amount can be quickly spotted by the operator.

In the case of the installation at Salem and Beverly, the liquid alum is held in a lead-lined wooden tank with a capacity of 5,000 gal. It passes by gravity from the tank, through a pneumatic control valve, and then through the Integral Orifice d/p Cell Transmitter. The flow is then sent into the suction side of the injector and delivered to the raw-water line at the point where it enters the plant. The alum is undiluted at the point of measurement. The pneumatic control valve has been used with both pH and conductivity-difference controllers and could be used with either a flow-ratio or flow controller.

Fig. 2 illustrates the physical arrangement of the alum tank and Integral Orifice d/p Cell Transmitter and injector within the plant installation. The pneumatic receiver is located in the Superintendent's office.

Fig. 3 is a typical recorder chart when using manual control. Various alum feed rates are shown, as well as a condition where the valve was slowly plugging, due to stirred-up sediment in the storage tank. Automatic control could relieve the plugging and maintain a constant or a proportional-to-water-flow feed rate.

Fig. 4 is an illustration of the Integral Orifice d/p Cell Transmitter, control valve and injector arrangement. It should be noted that the liquid alum is on one side of the Transmitter

and passed directly through and out the other side of the Transmitter.

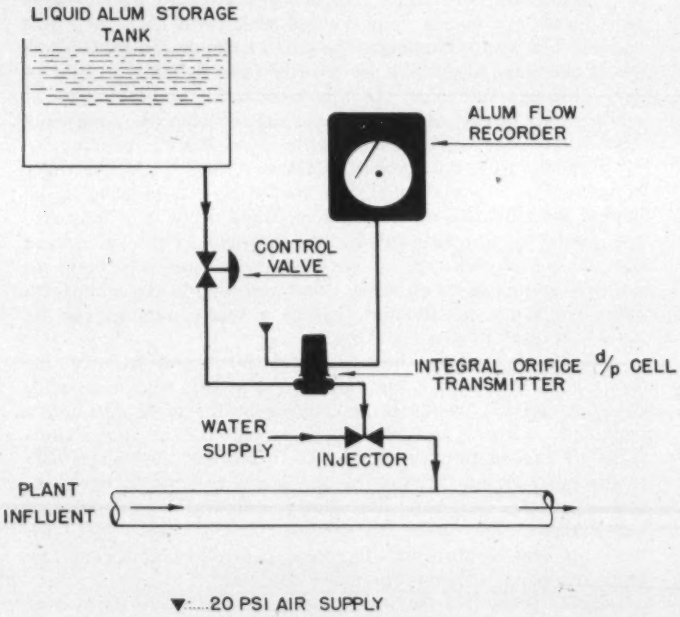


FIG. 2.—SCHEMATIC DIAGRAM OF LIQUID-ALUM FLOW MEASUREMENT AT SALEM-BEVERLY FILTRATION PLANT.

*Calibration*

At Salem and Beverly the Transmitter was calibrated by measuring the time for a given volume to flow. To obtain more information on the range over which this device is used, a calibration program was undertaken in the laboratories of The Foxboro Co. Fig. 5 illustrates the arrangement of the equipment for this work. It consists, essentially, of a source of liquid alum under a constant head with a manually adjusted valve downstream of the

Integral Orifice d/p Cell Transmitter. The temperature was controlled within one degree, to minimize the effects of viscosity and changing density.

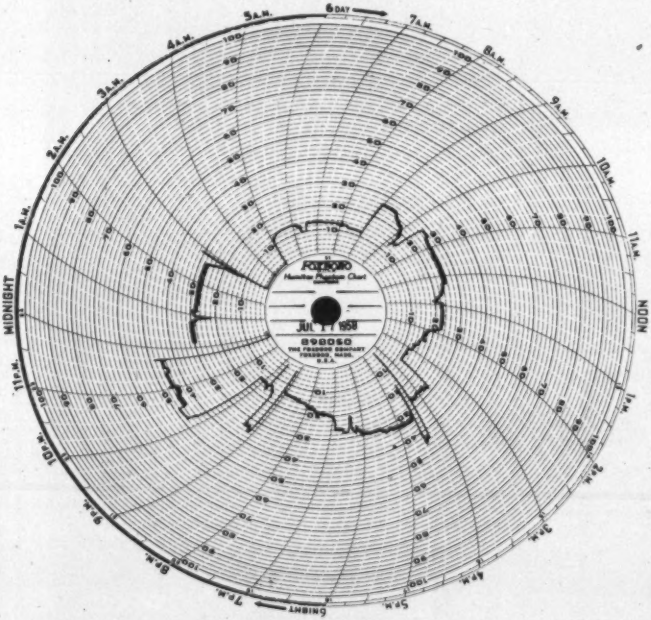


FIG. 3.—TYPICAL CHART FROM ALUM-FLOW RECORDER AT SALEM-BEVERLY FILTRATION PLANT.

Fig. 6 illustrates the calibration curves which were derived from that work. In this figure curves for water and for liquid alum at 80° and 100°F. are shown. It will be noticed that there are no calibration curves for the smallest and the largest orifices. In the case of the smallest orifice, the flow was so small that it fell outside the range of practical liquid-alum use. In the case of the largest orifice, the reverse was true, due to our limited

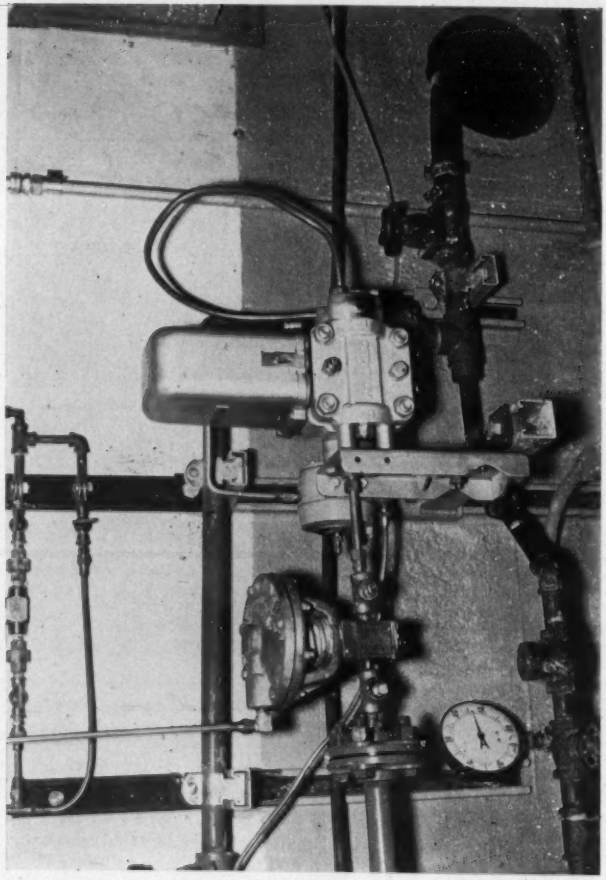

FIG. 4—INTEGRAL ORIFICE d/p CELL TRANSMITTER INSTALLATION, MEASURING LIQUID ALUM AT SALEM AND BEVERLY WATER SUPPLY BOARD, NORTH BEVERLY, MASS. *(The Foxboro Co.)*

supply of alum. In the case of the largest orifice, however, there is no question that it would function satisfactorily and behave similarly to the other calibration curves.

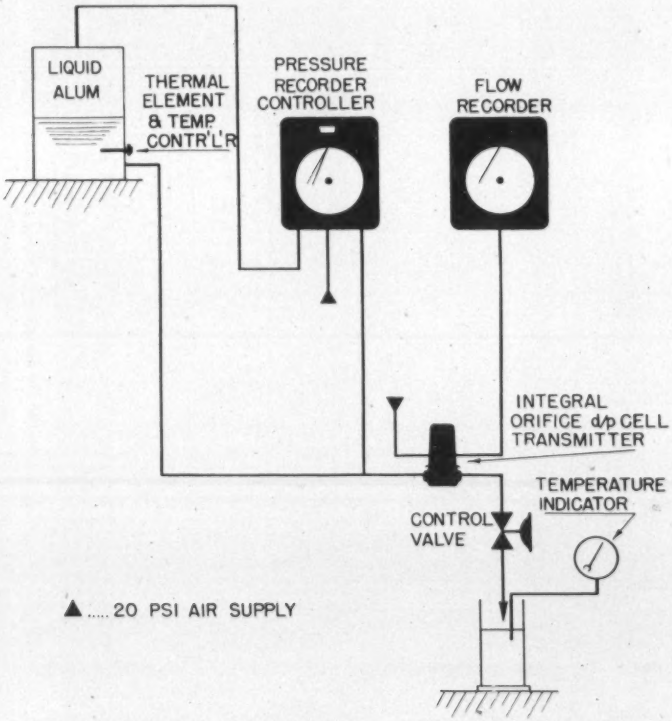


FIG. 5.—SCHEMATIC DIAGRAM OF TEST ARRANGEMENT FOR INTEGRAL ORIFICE d/p CELL TRANSMITTER CALIBRATION.

Some data from the calibration curves have been summarized in Table 2, which permits the selection of a differential and orifice for a particular installation. It also provides informa-

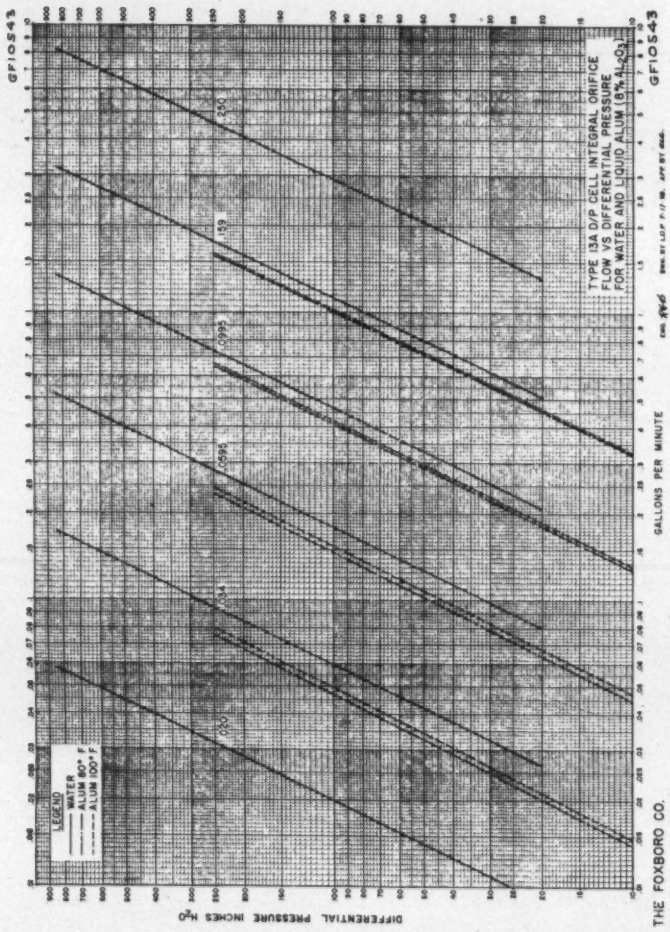
GF10543
TYPE 13A D/P CELL INTEGRAL ORIFICE
FLOW VS DIFFERENTIAL PRESSURE
FOR WATER AND LIQUID ALUM (8% Al2O3)
LEGEND
WATER
ALUM 60° F
ALUM 100° F
.350
.139
.099
.059
.034
.020
DIFFERENTIAL PRESSURE INCHES H2O
GALLONS PER MINUTE
THE FOXBORO CO.
GF10543

FIG. 6.

tion regarding the range of flows over which the Integral Orifice d/p Cell Transmitter can be used. The flow rate in gallons per minute has been converted to pounds of dry alum per day for each instance. It, therefore, can be seen that with the same instrument, by changing orifices and differential ranges, we can measure a flow as high as 12,500 lb of dry alum per day and as

TABLE 2.—TABULATIONS OF LIQUID ALUM FLOW (8% $Al_2O_3$) (Sp. Gr., 1.298) (5.1 lb Dry Alum per Gal) FOR VARIOUS INTEGRAL ORIFICES AND DIFFERENTIALS AT 80° F.

| Orifice diameter (in.) | Maximum Range 0-250″ $H_2O$ Gal per min | Lb dry alum per day | Minimum 1/10 max. differential = 25″ $H_2O$ Gal per min | Lb dry alum per day |
|---|---|---|---|---|
| 0.034 | 0.076 | 559 | .0240 | 176 |
| 0.0595 | 0.235 | 1730 | .0743 | 540 |
| 0.0095 | 0.650 | 4780 | .205 | 1510 |
| 0.159 | 1.70 | 12500 | .537 | 3950 |
| | Range 0-100″ $H_2O$ | | 1/10 max. differential = 10″ $H_2O$ | |
| 0.034 | 0.046 | 338 | .0145 | 106.5 |
| 0.0595 | 0.145 | 1065 | .0458 | 337 |
| 0.0995 | 0.410 | 3010 | .1295 | 952 |
| 0.159 | 1.00 | 7435 | .316 | 2320 |
| | Range 0-20″ $H_2O$ | | 1/10 max. differential = 2″ $H_2O$ | |
| 0.034 | 0.020 | 147 | .00632 | 46.4 |
| 0.595 | 0.064 | 470 | .0202 | 148.5 |
| 0.0995 | 0.18 | 1320 | .057 | 419 |
| 0.159 | 0.450 | 3310 | .142 | 1042 |

NOTE: Assume commercial dry alum contains 17% $Al_2O_3$.

low as 46.4 lb of dry alum per day. This is on the assumption that we do not drop below 0.1 of the maximum differential for any given range. In the case of the largest orifice, we are approaching the area where conventional differential-pressure cell transmitters and orifice plates can be used.

In the example we have used here, it can be seen that it is possible to achieve a rangeability in excess of 260:1 with the same piece of equipment.

Table 2 illustrates that it would be necessary to change orifices for major changes in flow range. This is easily done, since all orifices are interchangeable by removing two cap screws.

The purpose of this calibration was not to furnish a Transmitter calibrated to a specific flow range. This does not appear to be practical because of a wide variety of strengths of alum that may be used, effects of storage temperature, etc. We would recommend that a Transmitter of this type actually be calibrated by measuring the time it takes to fill a given volume at a uniform rate. For this purpose, the installation should have a flooded sample tap and downstream shut-off valve for convenience in plant calibrations. Also, a pressure tap and test gauge on the pneumatic transmission line at the Transmitter permits calibration by one man. In this way, all effects of concentration, temperature, etc., are calibrated out of the equipment. It also permits the calibration of the cell to be changed for another flow rate. Since the curves are straight on double-log paper, it is only necessary to obtain a few points for flow calibration of the equipment.

*Comparative Costs*

In any study of this nature, the practical consideration of cost is important. For this purpose, comparative figures are given for pH control, conductivity-difference control, ratio control and flow control. These figures assume the presence of compressed-air supply and, in the case of ratio control, a plant-influent primary device.

| | |
|---|---|
| pH Control | $2,000.00 |
| Conductivity-Difference Control | 1,700.00 |
| Ratio Control | 1,500.00 |
| Automatic Flow Control | 1,000.00 |

Automatic flow control is comparable in its functions to a liquid feeder or metering pump. It provides the additional advantages of flow transmission, recording and a convenient means of changing the feed rate.

This investigation of the flow of liquid alum—and more particularly, the application of the Integral Orifice d/p Cell Transmitter to this measurement—has shown this type of device to be capable of great flexibility due to interchangeable orifices and

wide adjustments of differential ranges. It also has produced none of the plugging difficulties which have plagued other types of devices. While this has been a discussion of the measurement of liquid alum, the Integral Orifice d/p Cell Transmitter is, of course, applicable to many other chemical flows. Since its construction is entirely of 316 stainless steel, it would, therefore, be ideal for measuring caustic solutions.

The authors would like to acknowledge the co-operation of the Chairman and Members of the Salem and Beverly Water Supply Board and the valuable assistance of R. K. Temple of The Foxboro Company.

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# ADVANTAGES OF STEEL TANKS FOR WATER STORAGE

BY J. A. MORLEY*

[*Read September 17, 1958.*]

Over the years there have been many ways of storing water. Our own ancestors depended on wells with the water raised by hand pumps, and barrels that caught rain water as it fell. With the increase in knowledge, storage vessels of many types have been developed, some of improved design and others of very doubtful value.

Before going into the specific subject of today's program, I believe it might be in order to discuss briefly some of the reasons for storage of any kind.

First, I wish to say that we in the steel-tank industry do not wish to assume any of the prerogatives of either the water superintendent or the consulting engineer. We only wish to work with them and furnish such information as may be helpful. However, I believe that some of the reasons for storage stress the need for dependable and proven methods.

The primary reason for storage is to have adequate water for domestic and commercial uses in sufficient quantities, where it is needed, and at pressures that make it available at all times. An additional factor to be considered is insurance. Properly selected and located storage often either reduces insurance rates or prevents increases.

The National Board of Fire Underwriters' "Standard Grading Schedule" says, "The introduction of storage either elevated and supplying the distribution system, or for suction supply, offsets to a greater or less degree the need of duplication in various parts of a system, the value of storage depending upon its amount and location." In general, the National Board recommends storage equal to up to five days of maximum consumption.

There are two general types of steel tanks. One is the flat-bottom tank with water stored from approximately ground level up to the high-water line. This type is usually called a standpipe, although technically a standpipe is a tank whose diameter is less than its height, while a tank with diameter greater than its height is a reservoir. The other type is commonly called an elevated

*New England Representative, Pittsburgh-Des Moines Steel Co., 1060 Broad St., Newark, N.J.

tank, or tank and tower. Most of these are tanks with wholly or partially suspended bottoms, supported on four or more columns. Some designs use single pedestals, and some have been built on three-column tripod towers. In general, the standpipe or reservoir is used where a natural elevation is available that will elevate the water to such height that all, or at least most of it, will flow by gravity, at an adequate pressure, to the point of use. The elevated tank is used when it is necessary or desirable to elevate an appreciable amount of water high enough above ground level to give the pressures desired. The capacity, location and height of either type of tank should be determined by a complete engineering study by someone qualified to do so.

Steel standpipes and reservoirs have been built in capacities from a few thousand gallons up to many millions of gallons. The most economical height of a flat-bottom tank is between 25 and 50 ft, depending on the capacity. However, the height is usually determined by local conditions, so that they are built from 15 ft high to more than 100 ft, with diameters to give the gallonage desired. The elevated tank is somewhat more standardized. Except for the smaller sizes, standard capacities vary by 100,000 gal up through 500,000 gal, by 250,000 gal through 1,500,000 gal, and by 500,000 gal above that point.

Until the middle 1930's steel tanks were bid in accordance with many and varied specifications. Most consulting engineers drew up their own specifications which had many variations. The tank companies had standards based on either insurance company requirements or variations thereof. About 1930 the American Water Works Association established Committee 7H, which published, in December 1931, tentative specifications covering riveted-steel elevated tanks and standpipes. These were published in final form in the A.W.W.A. Journal of November, 1935. With the rapid development of welding, it became almost immediately necessary to revise these specifications to include welded tanks. In cooperation with the American Welding Society the A.W.W.A. committee rewrote the tank specifications to cover both riveted and welded structures. These specifications were approved as "Tentative Standard" by the Executive Committee of the American Welding Society on April 4, 1940, and by the Board of Directors of the American Water Works Association on

April 25, 1940. They were approved as "Standard" by both organizations in 1941, and by the New England Water Works Association on September 24, 1942. Since that time, numerous revisions have been made. The up-to-date specifications are designated A.W.W.A. D100-55, the latest printing being October, 1957. The same booklet contains recommendations for paints and painting for both old and new tanks, as well as suggestions regarding repairing of old structures.

The important feature of the establishment of definite requirements for steel tanks to you, as members of the water-works fraternity, and ourselves as contractors, is the assurance that by following these specifications a product is assured that will meet the needs of your systems at the least possible cost. Definite standards are established, and little is left to individual peculiarities. Likewise the possibility of failure through human error is reduced to a minimum.

In addition to co-operating with the A.W.W.A. and American Welding Society committees, the leading tank companies are continually carrying on their own research. Speaking for the Pittsburgh-Des Moines Steel Company, whom I represent, we have spent many thousands of dollars over the years to give our customers a better, safer and more dependable product. About 15 years ago, we established a fellowship at the Mellon Institute in Pittsburgh, which has devoted itself to the improvement of our product. Within the past few months, we have completed a research laboratory of our own. The duties of the Research Director and his staff will be to find materials and methods that will result in better, safer and more economical storage for water and other items in which we are interested.

The results of the hours of study given to the standard specifications and the research by the individual tank companies are shown in the finished product. The erection of the tank is controlled by the same specifications and is done by crews experienced and schooled in this type of work. All welding is done by men who have passed specified tests, and on joints qualified to meet definite requirements. The welded joints are then inspected by the cutting of plugs from the joints, as outlined in Section 11 of the specifications, or by the x-ray method, as outlined in Appendix "A."

The erection of the steel is done by methods that vary to some extent by companies and even by individual foremen. The work goes on during all twelve months of the year. You can appreciate that it takes some pretty rugged characters to do this work in the weather that generally prevails in New England from December through March. However, in general, they are good citizens and very satisfactory representatives.

There have been several studies made of the life of existing steel water-storage tanks, for the purpose of predicting the probable life of such tanks and also to set up a basis for the amortization of the cost of these tanks. Charles W. Sherman read a paper before the New England Water Works Association on February 15, 1940, this paper being printed in the New England Water Works Journal of June, 1940, which gave information on the life of 111 standpipes throughout the New England States and New York State. Of these 111 standpipes, Mr. Sherman found that 44 had been abandoned, with a range in life from 2 to 56 years and an average life of 32 years. It was impossible to determine definitely how many of these tanks had been abandoned because of obsolescence, but the assumption was that the majority of them had been replaced because of the inadequacy of the size or the desire for storage in different locations.

Sixty-seven of these tanks were still in use in 1939, and at that time had an average age of 47 years. It is interesting to note that 20 years later many of these 67 tanks are still in use.

In the discussion of Mr. Sherman's paper by A. V. Ruggles that was printed in the December, 1940, issue of the New England Water Works Journal, there was a mathematical formula applied to the information given in Mr. Sherman's paper which gave a probable average life of 57.84 years to the 67 tanks still in existence, with a maximum of 100 years.

In the June, 1958, JOURNAL is printed a paper by Morris M. Cohn, which was read on September 16, 1957, in which Dr. Cohn has the following paragraph:

> "It is well to explore the way some manufacturers express preference for selling to private companies, rather than to public agencies. It is well, also, to explore why it has been said that the government 'buys by chance,' while private utilities 'buy by choice!' It is safe to say that private water companies buy with intelligence and economy; the question is: cannot public agencies profit from their practice?"

The American Water Works Service Co. of Philadelphia, Pa., has tanks owned by its subsidiaries throughout the country. It would, therefore, be safe to assume that they are interested in buying storage that will give them the greatest value possible.

On February 9, 1955, E. H. Aldrich, Chief Engineer of the American Water Works Service Co., presented a paper before the New Jersey Section of the American Water Works Association, in which he made the following statement:

> "Within the past few years, circular-prestressed concrete reservoirs have been successfully erected with considerable savings over the usual reinforced type, but are not fully competitive in cost with steel construction. Where exposed to severe freezing conditions, reservoirs still have a potential risk of damage, which only time can demonstrate to be imaginary. Where located in warmer climates or where completely covered with earth, prestressed reservoirs and tanks should fill an important need."

From the above quotation and the practice of the American Water Works Service Co. in buying primarily steel tanks, it would seem evident that they are convinced of the dependability and economy of steel tanks, both as to initial cost and as to maintenance.

As for maintenance, there will be maintenance on steel tanks and there will be maintenance on any type of standpipe or reservoir. The maintenance of the steel tank is fairly definite. As soon as the steel tank is put into service, it can easily be determined about how much should be set aside each year for the maintenance of the steel tank. Actually, in man-hours, the cost of painting steel structures has been reduced over the years. The cost in dollars has not varied greatly over the past 20 to 25 years. The maintenance of other types of water-storage structures is indefinite. Certainly, they all need at least periodic cleaning out and refurbishing of the outside to maintain appearance. Past experience with standpipes other than steel have shown large maintenance costs after they have been in service over a period of years.

The advantages of steel water-storage tanks are, therefore:

1. Exact design with adequate safety factor.
2. Precise control of fabrication, erection and welding.
3. Proven long life and dependability.

# CURRENT AFFAIRS IN THE WATER SUPPLY SERVICE IN ENGLAND AND WALES

BY CHARLES A. RISBRIDGER*

[*Read September 17, 1958.*]

Mr. President and Gentlemen,

Although I understand that I am to be given another opportunity of expressing to you, your Executive and your members the cordial fraternal greetings of the Institution of Water Engineers, the occasion will, I believe, be more a social function than an official proceeding and an account of what takes place thereat may not therefore find its way into your official records. As I am particularly anxious that our greeting shall be recorded I will accept the risks attendant upon repetition and express them here.

For those whom I have the honour to represent and even more so for me, this is an outstanding occasion in that I am able in person to convey to *you all* our most cordial greetings and to assure you that we attach the greatest value to the happy relations which exist between your Association and our Institution. On behalf of the Council and members of that Institution I express to your members through you, Mr. President, the sincere hope that the bond of friendship by which your Association and my Institution are tied will prove to be one of many strong strands to be spun into a mightier and inseverable bond of friendship between the two nations to which we are privileged to belong. I also express to you Sir, and to your Executive, my profound gratitude for inviting me to take part in your Annual Convention, and to submit this paper. Since the time available to compose it was short, I had to choose a subject upon which I could write without a great deal of research. I therefore decided to talk to you in a very general way upon the "State of the Nation," as it were, so far as water supply is concerned.

*Chief Engineer, Water Department, Birmingham, England, and President of the Institution of Water Engineers, London.

## Organisation of Water Supply

*The Minister*

The prime responsibility for water supplies rests with Her Majesty's Minister of Housing & Local Government, for the opening sentences of the Water Act of 1945 are as follows:—

> "Be it enacted by the King's most Excellent Majesty, by and with the advice and consent of the Lords Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the authority of the same, as follows:
>
> 1. It shall be the duty of the Minister "(of Housing and Local Government*)" to promote the conservation and proper use of water resources and the provision of water supplies in England and Wales and to secure the effective execution by water undertakers, under his control and direction, of a national policy relating to water."

The Minister exercises *general* control over individual water supply undertakers through statutes, through the necessity to obtain Parliamentary powers to enable them to proceed with projects to develop new sources of supply, and through the necessity to obtain his authority to borrow money to develop sources for which powers already exist.

*The Ministry*

He is assisted by the officials of his Ministry, through whom and the officials of the individual water undertakings normal contact is maintained between Minister and those undertakings.

Apart from this direct chain of control between Minister and undertaking there are other bodies playing important parts in assisting the Minister to fulfil the duties to which I have referred (see Figure 1).

*Central Advisory Water Committee*

The first, controlled by the Minister to the extent that its members are appointed by him, is the Central Advisory Water Committee, whose purpose is, in general terms, to advise him "upon matters connected with the *conservation* and *use* of water resources." The members, whose services are given voluntarily and without salary, are men of eminence associated with the many interests affected by, and affecting, the conservation and

*In the Act "Minister of Health."

proper use of water resources, such as river regulation, water supply, industry, water power, inland navigation, fishery, etc. At present three sub-committees are in being. One is appointed "to consider the extent to which the demand for water for domestic,

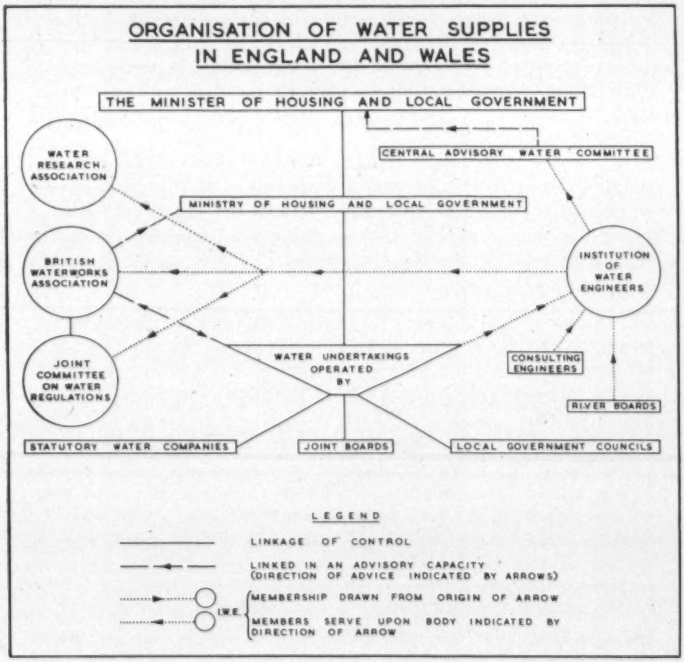
ORGANISATION OF WATER SUPPLIES
IN ENGLAND AND WALES
THE MINISTER OF HOUSING AND LOCAL GOVERNMENT
CENTRAL ADVISORY WATER COMMITTEE
WATER RESEARCH ASSOCIATION
MINISTRY OF HOUSING AND LOCAL GOVERNMENT
BRITISH WATERWORKS ASSOCIATION
INSTITUTION OF WATER ENGINEERS
JOINT COMMITTEE ON WATER REGULATIONS
WATER UNDERTAKINGS OPERATED BY
CONSULTING ENGINEERS
RIVER BOARDS
STATUTORY WATER COMPANIES
JOINT BOARDS
LOCAL GOVERNMENT COUNCILS
LEGEND
LINKAGE OF CONTROL
LINKED IN AN ADVISORY CAPACITY (DIRECTION OF ADVICE INDICATED BY ARROWS)
I.W.E.
MEMBERSHIP DRAWN FROM ORIGIN OF ARROW
MEMBERS SERVE UPON BODY INDICATED BY DIRECTION OF ARROW

FIG. 1.

industrial, agricultural and other purposes is increasing and is likely to increase; to consider the problems involved in meeting these demands, including in broad terms the cost; to consider whether there are any substantial economies in the use or cost of water which could be made without reduction in standards of

hygiene or in industrial or agricultural efficiency and to make recommendations." This, I suggest, is quite a comprehensive task.

The second sub-committee is "to review the current activities which contribute to our knowledge of the nation's water resources, to define the additional work needed to make a balanced survey of the quantity and quality of surface and underground water available for domestic, industrial and agricultural use; to advise on ways of collecting and interpreting the necessary information, correlating it with information from other sources, and publishing it." I suggest that they also will be occupied for a considerable time.

The third sub-committee is, among other things, "to examine existing legislation and the operation of the common law respecting the disposal from trade premises of liquid effluents not being radioactive effluents; to examine the problems, including financial problems, arising therefrom."

*British Waterworks Association*

Another organisation, the British Waterworks Association, is an association of water supply undertakings, comprising those operated by Local Government Councils (i.e. County, Borough, Urban District, and Rural District Councils), Joint Boards and Statutory Companies.

The undertakings are represented in the Association by members of the Councils, Boards or Companies and their officials, but in such proportions that the officials do not preponderate numerically. The main function of the Association is, broadly stated, to promote the interests of the water supply service, and in the fulfilment of that function it offers advice—sometimes sought, sometimes unsought—to the Minister.

It is not tied in any way to the Minister other than by a common desire for the good of the water supply service, albeit there have been upon occasions some divergency of view upon what is in the best interest of that service.

*Joint Standing Committee on Water Regulations*

Operating through the Association is the Joint Standing Committee on Water Regulations comprising representatives of the Association, the Water Companies Association, the Institution of Water Engineers, the Worshipful Company of Plumbers, the

Institute of Plumbing, the Royal Institute of British Architects, the Royal Society of Health and the manufacturers of water fittings—a wide selection from users and makers of water fittings.

Expressed in the broadest of terms the function of the Joint Committee is to prevent waste, misuse, and contamination of the water supplied by the undertakers. Of itself it has no mandatory powers and fulfils its function by acting in an advisory capacity to the constituent undertakings of the British Waterworks Association. The Committee examines and tests new water fittings and apparatus submitted by inventors, manufacturers and merchants, in order to determine whether they are likely to lead to waste, misuse or contamination of water. Lists of fittings to which they raise no objection are published for the information of water undertakers. The Committee, in conjunction with the British Standards Institution operates a licensing scheme whereby approved manufacturers enter into an agreement with those bodies authorising the licencees, upon the fulfilment of certain conditions, to mark with a standardisation mark draw-off taps and valves (faucets) and ball-valves made to conform with the appropriate British Standards, which were originally drawn up by the Committee and adopted by the British Standards Institution. They also played a very prominent part in the compilation of the Model Byelaws for the Prevention of Waste, Undue Consumption, Misuse or Contamination of Water issued by the Ministry of Housing & Local Government.

These model byelaws form the basis of the Byelaws adopted or to be adopted by water undertakings throughout the country, so that all byelaws are, or will be, identical apart from a few differences—mainly relating to permitted materials of construction —necessitated by differences in the chemical properties of the various waters supplied. The resultant uniformity is of great value to architects, heating engineers, builders and plumbers operating over large areas which take in the areas of supply of several water undertakings.

*Water Research Association*

Working in association with the British Waterworks Association, but governed quite independently of it, is the Water Research Association, the members of which comprise water supply

undertakings and some industrial firms serving the water industry. It is controlled by its members through its elected Council and assisted in its direction upon technical matters by a Research Advisory Committee consisting of engineers and scientists. It owes its birth very largely to the Institution of Water Engineers, which, recognising the urgent need for research in the water industry, set up a Research Committee in 1946 with a number of sub-committees each engaged upon the investigation of a separate subject. Being entirely voluntary and of a spare-time character, the work of these sub-committees was necessarily limited by the absence of funds; but with the example of what could be achieved even in those limited circumstances, the potential value of research was realised by the British Waterworks Association, whose Executive Committee undertook to establish a research organisation which was eventually incorporated in 1953. It now has an annual income of about £21,000 ($60,000) and a membership of about 250 water undertakings supplying between them over 70% of the country's water. It is hoped that the income will shortly be materially augmented by a grant from the Government Department of Scientific and Industrial Research.

The Association is at present engaged upon fundamental investigation of the process of coagulation, the means of detecting underground leakage, and the application of plastic materials to water distribution.

*The Institution of Water Engineers*

The Institution of Water Engineers, whose main object is to promote the advancement of water engineering in all its branches, differs from the British Waterworks Association in that the former is an association of individuals, whilst the latter is an association of undertakings. It draws its members mainly from engineers in the service of water supply undertakings, and consulting engineers, throughout the British Commonwealth of Nations, and from engineers serving River Boards.

Corporate members of the Institution must, as one condition of membership, be also corporate members of the Institution of Civil Engineers, the Institution of Mechanical Engineers or the Institution of Electrical Engineers and must be engaged in con-

nection with waterworks. Although the Institution as a corporate body owes no direct allegiance to any other of the organizations involved in the water supply service and to which I have already referred, it has members serving in them all and therefore indirectly exercises a material influence upon policy and practice in the water supply service.

In 1950 the First Edition of the Manual of British Water Supply Practice was published by the Institution. It is a work covering the many main subjects with which the water engineer must be familiar, and was written without fee by members of the Institution each considered expert in the particular subject allotted to him. It has become a standard work of reference for those engaged in the waterworks service.

A Second Revised Edition was published in 1954 and work on a Third Revision is shortly to be put in hand.

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With that brief account of the organisation of the water supply service may I now refer to a few matters at present occupying the minds of those engaged in it.

### Regrouping of Water Undertakings

In England and Wales there are about 950 water undertakings, of which 55 serve about half the population. It is part of the Minister's National Policy for Water to secure by amalgamations a reduction of the remaining 900 into organisations of sufficient magnitude to permit them to develop resources to the best advantage, to finance and supervise the development of major capital works and to employ properly qualified full-time staff.

The water supply industry as a whole acknowledges the wisdom of the policy, and it was the Minister's hope and intention that the necessary regrouping would therefore come about through voluntary mergers. To some small extent indeed this has occurred, but in spite of the fact that by the end of 1957 discussions involving some 700 undertakers were taking place, real progress towards the desired end is still slow, as might perhaps be expected because it is, I think, understandable that undertakers or an individual may agree with a policy but not be overeager to accelerate its application when it threatens to affect them or him adversely. There has therefore been some tendency to

believe that undertakings of a size less than that of one's own—but not one's own—should be merged. Pressure is therefore being brought to bear to ensure that the pace of regrouping is quickened, and as a spur to greater speed one or two mergers have been brought about by use of the Minister's compulsory powers. He has in fact made it quite plain that he will, if necessary, use those powers to see that a reorganised water industry, fitted to deal with the present and foreseeable demands, is achieved without loss of time. Let it not be thought, however, in view of what I have written, that the state of the water supply service in my country is bad. That it is not, is, I think, amply demonstrated by the fact that over 95% of the population enjoy a piped water supply and the extension of this boon to the remaining 5% in rural areas is proceeding gradually but continuously and no outbreaks of water borne disease have been recorded for many years. The aim is to make what is good better, in the most economical way.

## Supply and Demand

Since the end of the war, from the time that the nation got its breath back, as it were, the demand for water, mainly for industry, has increased at a very fast rate, as may be illustrated by some figures relating to the undertakings which I serve, the City of Birmingham Water Department, and which are reasonably typical of other undertakings serving industrial areas. Since 1945 the domestic consumption of water per head has remained substantially constant at a little more than 20 gallons per day. Industrial consumption on the other hand has increased in the same time from 14 to 25 g.h.d., so that if that rate of increase continues the industrial consumption will have doubled itself in less than 17 years. The population served is about 1¼ millions. Similar increases in demand have perforce led many undertakings to seek new sources of supply, and whilst the country as a whole is blessed with a rainfall sufficient to meet all foreseeable demands, sources near to the large centres of population have, in general, already been fully exploited and the new sources must therefore generally be more remote and more expensive to develop. Furthermore, in a small, thickly populated country such as England and Wales the development of surface water sources inevitably affects the interests of many people, and in a democratic society

every objector must—for which let us be truly thankful—be given the opportunity of having his objections fully examined. A new source cannot therefore be developed except with the authority of an Order of the Minister, or an Act of Parliament. Before an Order is made any objectors whose objections have not already been met in private negotiation may state their objections at a public enquiry conducted by officials of the Ministry. Before an Act is obtained the Bill is examined in detail by Parliamentary Committee at which all objectors may be heard. Considerable time must therefore elapse between the initiation of a development project and its realisation, thus making it necessary to forecast well ahead the probable future demands.

It may have surprised my listeners that the domestic consumption of water in the Birmingham area is of the order of only 20 g.h.d., for I am aware that the corresponding figure in the United States is generally very much greater. At the time of writing I regret that I know little of the circumstances which give rise to that larger consumption—a deficiency in my knowledge which I hope to make good, at least partially, before I return home—but I can mention some of the circumstances which lead to the comparatively low domestic consumption in England and Wales. The comparison will no doubt be the more surprising when I tell you that, with one exception, no water undertaking meters a supply for domestic purposes only. The main reasons for the low figure are as follows:—

1. The climate is normally fairly equable in temperature, prolonged periods of hot dry weather or hard frost being rare exceptions, whilst rainfall is usually well distributed throughout the year.
2. Every water pipe and fitting must comply with the requirements of the undertaking's byelaws, and all are inspected for compliance therewith before the installation is connected to the mains. Many undertakers require fittings to be installed in their area of supply to be submitted to them for testing, and if approved, stamping with their identification mark.
3. An effective waste detection and prevention service is maintained. As an example the Birmingham Water Department employs about 30 Waste Inspectors, engaged constantly in house to house inspections and tests and in the operation of a re-washering service free of charge to the consumers. This service makes for good public relations and the fact that these visits take place keeps the need to avoid waste and misuse of water in the public mind.

4. Good public relations are also fostered by illustrated lectures, film shows and brochures given upon request to any organised party, whilst visits to the works are generally encouraged.
5. Garden watering by means of sprinklers is permitted only if the supply is metered, whilst the use of a hose for any purpose, from a supply which is not metered, is permitted only upon payment of a fixed extra annual charge and upon the condition that it will be held in the hand during use and not left running unattended.
6. Flushing cisterns of a capacity greater than 2 gallons are with few exceptions not permitted and they are so designed that even if the overflow or warning pipe is stopped up whilst inflow continues, water cannot flow down the flush pipe. Overflow from cisterns is required to be discharged where it can readily be seen, in order to act as a warning of the defect giving rise to the waste. Flushing valves are not accepted, on the main grounds that, if defective, the waste water flows away via the lavatory pan with no inconvenience to the consumer, and thus with little incentive to him to repair the defect, and that unless systematically maintained they are apt to deliver a flush greater than the permitted two gallons.

The domestic consumption per head in the Birmingham area is lower than that for the country as a whole, which, of the order of 30 g.h.d., is still a reasonably low figure. It is often suggested that in the interests of economy and equity, domestic supplies should be metered, a suggestion with which I emphatically disagree having regard to the circumstances existing in the British Isles. From the economic point of view, starting from the fact that the charge for water for domestic use in England and Wales varies from about 5d to 10d per ton delivered, it is demonstrable from known figures that the cost of producing the meters, installing them, housing them, reading them, maintaining them, recording their readings and calculating the charges, would be such that if the money thus spent in an endeavour to reduce consumption were spent upon measures to produce water, the consumers could have more water at the same cost as that which they would have to pay for less water. It seems to me absurd, in a country liberally provided with rain, to devote money which could be used to produce more of an essential commodity, to the manufacture and maintenance of devices designed to induce consumers to use less.

On the question of equity there is no temptation to collect and hoard water as one might collect money or diamonds, nor to

over-indulge as one might do with good food or liquor. For the basic domestic needs there are limits to the quantity one can use, albeit these limits are increasing as the standards of sanitation and comfort increase. The standards differ of course as between one income group and another, but the consequential differences in the quantity of water used for domestic purposes are, to a great extent, taken account of by our method of making the charge for water a proportion of the value of the property supplied. It follows that the only remaining inequity is that which would arise from the deliberate or neglectful misuse or waste of water by some consumers. Whilst I must agree that in strict justice the few who so misuse a water supply should pay for that misuse, nevertheless from the practical point of view, the adoption of universal metering to achieve that end would be quite wrong, as whilst it might deter the small minority who misuse and waste water, it would penalise also the greater number who do not, because the adoption of metering would increase the cost of water to all.

I assure you that I do not for one moment presume by what I have said to suggest that you cease to meter, or refrain from an intention to meter, domestic supplies in your country where circumstances may differ materially from those in mine. I have merely tried to explain why we do not meter them in the climatic, historical and social circumstances pertaining to our country.

## Utilisation of Rivers

Underground sources of water within economical reach of the large centres of population in England have little or no margin of capacity over the present rate of abstraction. Most of them are in fact prescribed areas from which abstraction is controlled by the Minister in that no one may without his licence to do so sink new boreholes or wells for the abstraction of water therefrom, or increase existing abstractions, nor indeed sink borings to prospect for or abstract minerals. Large supplies of water to meet the increasing demands must therefore be obtained from the rivers. At the end of the last century and the beginning of this, when major sources of supply were developed for several of the large cities such as Birmingham, Manchester and Liverpool, it was necessary to impound the unpolluted upland waters remote from

centres of population and to deliver them through long aqueducts, because the only acceptable means of purifying the water was the slow sand filter. With the development of chemical treatment and rapid filtration the trend to-day is to abstract water from the lower reaches of rivers.

In view of the many uses which our rivers serve and of the increasing demands, it would seem to me both prudent and equitable that no authority or person should be permitted to abstract water from a river without contributing to its regulation by means of balancing reservoirs.

In implicit advocacy of such a policy I have foreseen the establishment of a River Regulating Authority to whom applications to abstract water would be submitted, and who would be responsible for the provision of the compensating reservoirs out of the revenue derived from a charge per unit of water abstracted. In the past there has been no uniformity in the compensation required of abstractors. For instance Birmingham, in order to obtain powers to abstract 75 m.g.d. from the river Elan in Mid-Wales, was placed under an obligation to discharge to that river every day throughout every year 29 m.g.d., despite the fact that the dry weather flow has at times been as little as 5 m.g.d. On the other hand some water supply authorities abstracting water from the lower reaches of a river have powers to do so without providing any regulating reservoir, and whatever the state of flow of the river.

In some parts of the country the irrigation of farm crops is increasing, and in the absence of regulating reservoirs this use of water could be a serious potential threat to other river users, for the amount required for irrigation varies inversely with the amount available in the river. Obviously a farmer would not be in a position to construct a compensatory reservoir, but a charge for water abstracted could be devoted by a controlling authority to such a reservoir or reservoirs constructed to compensate for many abstractions. I have foreseen also that the development of regulating reservoirs to compensate the river at times of low flow might in time be extended for the purpose of flood control as well. In a small very highly industrialised country I am convinced that some such control will eventually be essential.

## Control of Pollution

With an increasing use of the lower reaches of rivers for potable water supplies the prevention of pollution becomes correspondingly more desirable. The Rivers (Prevention of Pollution) Act 1951 placed upon the River Boards the general duty of making "provision for maintaining, or restoring, the wholesomeness of the rivers . . . of England and Wales." The Act makes it a punishable offence to cause or permit any poisonous, noxious or polluting matter to enter a stream, or to permit any matter to enter a stream so as to tend to impede the proper flow of the water in a manner likely to lead to a substantial aggravation of pollution from other causes.

The River Boards are empowered also to make Byelaws prescribing standards for discharges into rivers from sewage disposal works, trade premises, etc. In order, however, to ensure that sewage disposal authorities and industry should not be forced all at once to expend large sums of money to enable them to comply with the Byelaws, the Act also prescribed that, in general, for a period of seven years from the passing of the Act, no proceedings should be taken against an offender without the consent of the Minister. The purpose of this restriction was to ensure that in the difficult financial circumstances resulting from the war local authorities and industry should not be unduly hampered in their development by the necessity to comply with new standards. Whilst from the point of view of water suppliers and others interested in the purity of rivers this was something of a disappointment, nevertheless the wisdom of proceeding slowly towards the eventual heaven was recognised in this case. Heaven —a state of supreme bliss—is perhaps not quite the apt word to use in this context, for some compromise standard must be accepted having in mind the necessity for the community to dispose of its liquid wastes on the one hand and to supply itself with potable water on the other, with the maximum combined economy.

The wisdom of a recent recommendation that the seven year period of grace be extended by a further three years is not so generally recognised. We are comforted, however, by the knowledge that the potential powers conferred by the Act are being used as a means of persuasion towards the end which at present

cannot be obtained by force of law, and that already some improvement in the condition of our rivers has taken place.

## Conclusion

I hope that this brief account of affairs relating to the water supply industry in England and Wales will have demonstrated that steadily and surely we are working to the eventual end that every inhabitant, apart from those most remotely situated, shall be provided with a piped supply of pure and wholesome water, at the minimum cost, by undertakings not too large to be ungainly and impersonal, not too small to lack the means to be self-sufficient, working under unified control in matters of principle, yet each with its own individuality and its own methods of solving its own peculiar problems.

It is my firm belief, Mr. President and Gentlemen, that such an end is well worth striving for.

# OFFICE PROCEDURE

BY MARK F. CROKER*

[*Read September 17, 1958.*]

The subject matter on the program for discussion by your panel this afternoon is "water-works management," an administrative operation, generally speaking, of municipal government or private utility, which has received rather scant attention over the years by our New England association as a topic for discussion or paper, due apparently to the availability of a wealth of material based on technical developments or construction in the water-supply field. Nevertheless, it must be pointed out, in respect to its relative importance as a subject for discussion by a superintendent's session, that municipal water departments or private water utilities do not run themselves, regardless of how well conceived, and unless skillfully managed, will not be productive of the technical progress or development upon which our many excellent association programs are based.

One of Webster's definitions of the term "management" reads as follows: "Judicious use of means to accomplish an end." Thus, water-works management may be described as the efficient, economical and skillful employment of funds, staff, structures, facilities, equipment and tools of a water utility for the purpose of adequately supplying a city, town, district or area with potable water.

This general subject has been broken down into subdivisions by your program committee for our panel discussion, the writer's specific assignment being "office procedure." The term "procedure" is variously defined as "progress, operation, conduct or method." Experience has demonstrated clearly that smooth and efficient "office procedure" is a very important link in the chain of successful water-works management.

In the opinion of the speaker, the purposes of this discussion would best be served by a general description of the methods, forms, machines, etc. employed by the clerical staff of the Newton

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water department which, when duly co-ordinated, form the office system for administration and control of the operations of the department. Such a description obviously should be prefaced by a brief outline of the size and scope of the operations under discussion.

The city of Newton, Mass., is a suburban community in the metropolitan area of Boston, currently having a population of approximately 90,000, residing in an area of about 18 sq mi. The water department serves 100% of the population through a main pipe system of 290 miles and 21,900 services with an installed total of 24,365 meters. The water supplied from the metropolitan system in 1957 totalled 3,838,000,000 gal, and revenue realized from all operations approximated $950,000. The permanent construction and maintenance crews with the supervisory staff total 51.

Operations of the department embrace all functions normally handled by a water utility with the exception of engineering, which is performed by the city engineering department, collection of revenue, which is the responsibility of the city collector and treasurer, and purchasing, which is channeled through the purchasing office.

From a clerical standpoint, the entire department operation is handled by a main office staff of six and two male clerks at the supply yard. The following is a brief résumé of procedure in the main office:

*Duties of principal clerk and secretary to department head*

Handling commissioner's dictation, checking appropriation balances frequently, and advising commissioner of status of all accounts. Petitions for water main extensions: The applicant signs a petition (1), which is referred to the engineering department for an estimate (2).* Upon receiving the estimate, the applicant is advised by mail of the amount of the guaranty payment (3) (15% of the cost, returnable in 5 years or less, depending upon water consumed on the extension). After the payment of the guaranty, the department forwards a letter to the mayor, requesting an appropriation for the extension. When the

*Numbers in parentheses indicate the total number of forms mentioned up to that point in the paper.

funds are appropriated by the board of aldermen, if the main is to be constructed in a private way, a release (4) is obtained from the abutters, allowing the city to enter the street and lay the main. When the release is received, it is forwarded to the city solicitor to be filed at the registry of deeds.

*Meter Tests*

Reports of the results of meter tests are mailed to the customer. On consumer accounts, where complaints of high bills are not settled by a form letter, an analysis of the account is made and a detailed explanation given.

On large construction accounts which involve contracts, a constant record is kept of encumbrances and expenditures, also the total cost of the contracts as certificates are issued.

*Budget* (5)

The budget form and procedure instituted this year in Newton are based upon a classification of the expenditure accounts of the city. Previously, a so-called "line item" budget had been in use. Through "classification" an orderly, systematic arrangement or distribution is provided, whereby objects, classes and items of expenditure which are closely related in character and purpose are brought together in sets or groups, thereby permitting a uniform and consistent base for comparing data with that for other periods and other governmental units. Such a budget format lends itself to coding, which provides greater economy of space and time in recording and reporting expenditures and transactions. The changeover involved considerable time and effort, inasmuch as it was a complicated task to transpose the 1957 expenditures from the old set-up to the new. As the year progresses, little difficulty has been experienced by the water department regarding charging expenditures properly, and the coded form of budget seems to be working out very well.

Since Newton employees are under the jurisdiction of Civil Service, all data concerning employees must be cleared through or reported to the Division of Civil Service.

A secondary check is made of invoices to be paid before approval by the commissioner.

*Duties of senior clerk #1*

The hourly employees are required to use a time clock which is located at the supply yard. The payroll is made up from the time cards, in the city hall office. Entries are made on two different types of daily payroll forms by the time and construction clerk, for use in allocating charges to budgetary and special appropriations and also for furnishing information regarding time spent on chargeable jobs. A classification (6), which indicates the budget items to which the payroll is to be charged, is prepared in conjunction with the payroll and forwarded to the accounting department. A record of the overtime (7) worked is prepared weekly and a copy sent to the director of public works and to the mayor's office. All requisitions (8) for materials or services for the department must first be approved by the commissioner. They are then sent to the purchasing agent. Shipping orders (9) on contracts are sent directly to the comptroller for encumbrance without recourse to the purchasing office. Invoices are processed promptly to take advantage of discounts, approved by the commissioner and forwarded to the accounting department, which in turn refers them to the city treasurer for payment. Standard invoices (10) are furnished by the city for the use of vendors.

All maintenance work of a chargeable nature is billed (11) promptly, referred to the commissioner, then mailed out to the customer. A duplicate bill (12) is scheduled and forwarded through the comptroller of accounts to the city collector. Daily entries are made of payroll and material charged to new main appropriations.

*Duties of senior clerk #2*

All data concerning meter installations and changes are forwarded to the office from the supply yard. These data are entered on the meter reader's books. When a change in occupancy occurs, where the party involved pays the water bill (it may be either the owner or tenant in Newton) a reading is taken when the department is requested to do so, and a final bill is sent, or an abatement is given against the advance charge. All complaints (13) of high bills are referred to the head meter reader and inspector. He reports (14) back to the office after he investigates,

and a form letter (15, 16) is sent to the consumer. All street openings made by the department are reported to the street department and director of public works weekly.

*Duties of senior clerk #3*

When a new water service is desired, the applicant signs a form (17), and the cost of the service is estimated by the water-system superintendent. The estimate (18) is typed and mailed to the applicant. When the estimated cost has been paid, it is reported to the water department by the collector's office. An order to proceed with the work is made out and a number assigned to the service. When the service has been completed, the material used and the employees' time is entered on the service order, also any equipment involved and returned to the office. The service cost is figured, and complete details of the installation are entered in a service book, which is a permanent record in the department. The cost of the service is typed (19), and a schedule (20) reporting the cost of the service is forwarded to the comptroller and collector, indicating whether or not a rebate is due the applicant. If a rebate is due, a check is sent by the city collector and treasurer.

A record of guaranty payments on new mains is set up, and water bills as they are rendered are entered against each main. When the amount of water consumed and paid equals the amount of the guaranty payment, up to a five-year period, the amount of the guaranty is rebated to the applicant. At the end of five years, the amount of water consumed is returned although in all cases, it may not equal the guaranty payment.

On delinquent accounts, a list is received periodically from the city collector reporting the unpaid bills. A form letter (21) is sent from the water department, which usually results in a considerable number of payments. The letter states that the water may be shut off but does not actually threaten to do so. Subsequently, another form (22) is sent, stating that a lien will be filed against the property if the bill is not paid. In the spring of each year, the collector forwards a record of the unpaid water bills of the previous year to the board of assessors to be added to the real-estate tax bill. It is the experience of the city collector and treasurer of Newton that the new lien law has been an ef-

fective means of enforcing collections of water bills practically 100%. It is his opinion that it is a beneficial setup to have the city collector responsible for the collection of water bills, rather than the water department.

*Duties of senior clerk #5*

Water-billing (23) operation, which will be described in detail later. A list (24) of those reporting as sick is sent to the city physician daily, which he may or may not check for validity of the sick leave, depending on the employee. A card record of the sick leave (25) and other leave (26) (sickness or death in family, or religious observance) is kept in the department. Upon returning to work after sick leave, each employee is required to file a form (27) stating the nature of illness, etc., under the penalties of perjury. Addressograph (28) changes are made on a graphotype.

*Duties of junior clerk #6*

Water billing. Analysis of the expenditures of the department in considerable detail, including payroll, services and material.

*Water-billing operation*

One and a half years ago we installed one Burroughs Sensimatic F403 machine to bill our 23,000 metered water accounts. While machine-billing procedures were not new to us, we were skeptical about the fact that the Burroughs people proposed only one unit to replace two competitive billing machines. We knew that their machine had a reputation for being fast, but a two-for-one swap appeared quite drastic. After extensive investigation, we purchased the Burroughs machine. When the delivery date arrived, we requested that we be permitted to hold one of the old trade-ins, to serve as a standby during our first billing cycle. We never once took the cover off the old machine during the initial billing period. Not only did the one new Sensimatic easily replace the two competitive machines and free a billing clerk for other office tasks, but it also availed us enough spare machine time so that we were able to put our departmental budgetary encumbrance ledger accounts (29) and analysis of expenditures (30) ledgers on the same single machine. In addition

to these tasks, we have provided for future changes by having a bill and ledger system built into the machine program, since there has been a great deal of interest in this kind of system and its merits. We have provided for it in case we need it. The billing plan which we presently use is the register-sheet plan, wherein a water-charge commitment sheet (31) and water-charge register sheet (32) are produced as a by-product of writing customer bills. The bill which we prepare is a 5-part snap-out form, which we commit to the city collector for mailing and follow-up. But let's start at the beginning.

The city of Newton is divided into 3 districts for billing. We read and bill one complete district at a time. As the meter readers progress throughout the assigned district, our preliminary office work for the same district is coordinated, so as to be ready for billing upon the return of a completed meter book. Using Addressograph units, we automatically run off the name and address and file number of each customer, plus assigning a collector's bill number to both the commitment and register sheet. This is all accomplished in one operation through our Addressograph machine. We next take the same set of Addressograph plates and rerun them through the Addressograph machine, to head up our 5-part customer bill. We exercise care to insure that the automatic bill number assigned to the collector's commitment sheets and to the bill correspond. We are now ready to work with the meter book prior to billing. The billing-machine operator goes through the completed meter book and checks the extension of the consumption in the book which the meter reader has figured. She then refers to the current rate chart (33) for determining the proper rate to be charged and enters it against the consumption. When this has been done she gathers the register and commitment sheets, plus the corresponding bills for this book at the machine, ready to commence billing.

Here I might point out a few of the features which we asked to be included in our new Burroughs machine: (A) Special large carbon type—to insure the maximum of legibility on our 7 carbon-copy impressions; (B) Proof of consumption lock, which proves the accuracy of the consumption computation; (C) Flexible keyboard date section for instant change of the meter-reading date as required on the bill.

After setting the meter-reading date on the machine keyboard, the operator inserts the bill in the machine and enters the present meter reading on the bill; next she copies the previous meter reading from the meter book; and finally the consumption as written in the meter book. At this point, the machine takes over and crossfoots the difference between the present and previous reading, simultaneously comparing the machine results with the meter-book calculations. If they agree, the machine prints the correct consumption on the bill and spaces over to the water-rates charge column. If, however, there is an error, the Burroughs machine locks and will not operate until the correct equation is entered on the bill. The machine will not print out an incorrect consumption on the bill.

In the event of a machine warning lock, the operator immediately looks for two kinds of possible error: (1) The meter-book pre-extension of consumption is incorrect or (2) the operator copied the meter-book data incorrectly. In either case we have not spoiled the bill. The operator merely spaces the bill up one line and re-indexes the correct figures. The machine compares the accuracy of the new figures and prints out the consumption if all is in balance. Using the machine-printed consumption figure, the operator refers to the meter book and enters the amount of the bill in the machine.

These steps are repeated for each new bill as it is prepared. Upon the completion of the meter book, the machine is automatically totalled for control purposes and proof. Upon finishing a section, we send the completed bill and commitment sheet to the city collector for mailing and collection. We retain the register sheet for our office records. Our 5-part water bill has proven to be very useful to the city collector. The first two copies are mailed to the customer and serve as a bill and a duplicate to be retained by the consumer. The third copy is receipted when payment is made. The fourth and fifth copies of the bill are retained in the collector's office and serve as a duplicate bill file. The fifth copy of the bill serves as a demand notice in case of delinquency and is mailed by the collector 30 days after the original notice is issued. To complete the cycle, the city collector enters the receipted payments in the commitment sheets, using the billing number as a fast means to locate the proper account.

All office machines used in the operation of the department are: 7 typewriters, 3 Monroe Calculators, 1 Allen-Wales tape adding machine, 1 Graphotype, 1 Addressograph and feeder, 1 Index-card writer and proofing machine, and 1 Burroughs Sensimatic billing machine.

## Supply-yard Office Procedure

With the exception of stock used on special projects, new main construction, automotive and equipment repairs, and supply-yard maintenance, all stock is ordered only when the stockpile has been depleted to a prescribed point. Until this prescribed point of depletion is reached, certain records are kept, showing prices, quantities, appropriation charges, etc., which are necessary for the re-ordering of stock.

### *Stock Requisition*

A stock requisition (34) is required before any stock is issued or removed from the yard. This stock requisition, when correctly processed, will show the location and description of work, appropriation charges, quantities and description of materials requisitioned, unit and total prices of each item, and signatures of persons taking part in the transaction. Quantities on each item of stock used are recorded on the proper index card in the perpetual inventory and appropriation charges records, and then the stock requisition is sent to the cost office.

### *Purchase Requisition*

When ordering of stock is necessary, a purchase requisition (35) is made out by the storekeeper in duplicate. The original is forwarded to the commissioner's office for processing, and the duplicate is filed to await the issuance of a purchase order from the purchasing department. All pertinent information, such as quantity, description of material, catalog numbers, estimated costs and appropriation charges necessary in ordering stock, is recorded on the purchase requisition.

When the purchase order is issued and a copy is sent to the storekeeper, the information on the purchase order is recorded on the proper index card (36) in the perpetual inventory.

*Material-Receipt Records*

A material-receipt record (37) is written out for all stock and supplies, etc., received at the supply yard. This material-receipt record shows the amount of stock and supplies received on each full or partial delivery of every order. If an order is incomplete, it will show the quantity due and the date of partial shipment. The above information on each delivery is then recorded both in the daily diary and on the proper index card of the perpetual inventory.

*Perpetual Inventory Index Card*

Each item of stock, supplies, tools, equipment, etc., has an individual index card in the perpetual inventory. These index cards show a daily permanent record of all information pertinent to the purchase, receipt and disposition of all stock, supplies, tools, equipment, etc.

*Service Records*

All information regarding each individual service, such as payroll time, stock, equipment used and tyes, is entered daily in the service book. This information is transferred to its proper place on each service-installation order sheet (38). The original is sent to the city hall office, and the duplicate with a copy of the tye drawn on the back is sent to the engineering department. After permanently re-tying each service, the engineering department prints a tye card (39) for our use, to be filed in our tye-card file at the yard.

A pressure-survey card (40), showing service-installation information, is made out for each pressure-survey request received. When the test is made, the test data are recorded by the maintenance men and returned to the foreman for further action.

*Meter Records*

All calls for meter changes, removals, etc., are permanently recorded in the daily diary, and all pertinent information referring to the disposition of these calls is recorded in the repair book by the repairmen. This information is checked and then copied on to "meter change or removal" (41) slips or "meter setting" (42) slips by the storekeeper, in preparation to being entered on

the permanent records [namely, meter-history cards (43) and meter-index cards (44)]. A meter-repair job slip (45) is filled out by the meter repairman for every meter repaired. It shows a breakdown of parts and labor costs, registration tests on various flows before and after repairs, and a secondary check on the correct number and reading of each meter. This information is recorded on the meter-history card.

Other forms used are: Missed-reading sheets (46), missed-reading post cards (47), courtesy post card to consumer *re* plumbing leaks (48), hydrant-meter application (49), application for temporary water for construction purposes (50), notification (51) of shutting off water to consumers for the purpose of making repairs to the water system, abatement forms (52), hydrant-inspection cards (53), weekly report of gasoline used by each vehicle (54), inter-department transfer bills (55), work in operation (56), daily report of meters read (57) and yearly individual compensation record (58).

# ENGINEERING AND OPERATION OF THE WATER SYSTEM

BY PETER C. KARALEKAS*

[*Read September 17, 1958.*]

It is predicted that by the year 1975 the population of the United States will be increased by 49 million people, bringing the total population up to 221,000,000. This means that the average water works will have to furnish 50% more water in the year 1975 than it does at the present time. Therefore, water-works engineers must, in addition to supplying the present demand for the community, be prepared for the future.

The role of the engineer is most important in a well-operated water department. Engineering decisions are involved in all problems arising in the design, construction, operation and management of a water department.

Let me say from the start that many have often thought of the "big system man" and the "small system man" as two different kinds of men. I say that they are not because the same kind of man is doing the same kind of job, with possibly different approaches. You just can't say that one man knows all the answers, while the other does not. As a matter of fact, there are outstanding examples of fine management all along the line, from the smallest town to the largest city.

To meet this challenge the water-works engineer should be planning now for the expansion of the water facilities. In order to accomplish his primary mission of supplying his district with an adequate and potable supply of water at a reasonable cost, the water-works engineer must have an adequate staff of technically trained associates.

The competition for securing young graduate engineers in the industrial and commercial fields has put the municipal water executive at a considerable disadvantage. The salary, retirement benefits, vacation and incentives of private industry surpass any advantages the Civil Service employee once enjoyed.

*Chief Engineer, Municipal Water Works, Springfield, Mass.

In the past few years, starting salaries ranging up to $500 per month were not uncommon for young graduate engineers in private industry. To reach such a salary bracket in the municipal field would take years of service.

In this age of atomics, electronics, automation and push buttons, it is more imperative that the cities secure their fair share of these engineering-school graduates, as a very technical background of mathematics, electricity and physics must be learned in an academic background and cannot be acquired by either in-service training or looking over someone's shoulder.

During the present year, legislation was passed in the General Court of Massachusetts, permitting municipally owned gas and electric utilities to give scholarships in engineering schools to selected high-school graduates. These students would be employed by the city utilities during the summer vacations. Upon graduation from engineering school, they would incur an obligation to work for the utility for a period of years. This scheme will insure an influx of young engineers to the cities. Such a plan would expedite the problems of the water-works executive, and it should be implemented by water-works management.

Since these engineers are not available at the present time, we must secure the services of consulting engineers. It will be their task to carry out the necessary studies, preparations of the design, plans, specifications and other documents that are required. The water-works engineer must spend many hours working with the consulting engineers of his choice to reach the final goal, the finished product.

Under more normal conditions, the water-works engineer can produce the studies and projects necessary to maintain his system at its highest operating efficiency.

When designing additions to the existing water works, one must secure and study past water-consumption records, going back at least 30 years, if possible. The maximum hourly and maximum daily water uses are most important when planning and designing system capacities.

Estimating the future population of your city or town can be accomplished by projecting the past growth of your community and comparing it with past growths of similar-sized cities.

The assessors, planning boards and telephone companies also have estimates of future population which are of value.

Our major problem in this phase of future planning is per-capita water-use estimates. Water use per capita has been increasing during the past 20 years and, without a doubt, will continue to increase. To estimate that increase, one must use his own records to plot and determine a reasonable percentage increase. An increase of about 1% per year is a yardstick to remember.

In designing water-works structures and facilities for the future, two principles can be followed. Design to maximum capacity reservoirs, lake or river intakes, transmission mains, supply lines and distribution enlargements that are expensive to duplicate or increase. Design for 50% larger than present capacity treatment plants, pumping stations, wells, distribution storage and sections of distribution systems.

In the above design, the requirements of the National Board of Fire Underwriters must be met. To meet these demands, water-storage facilities must be constructed, and the type and location of storage is a matter which must fit the individual problem.

One of the most important and most costly items of a water works is the transmission and distribution system. The system must be designed to contain enough capacity to provide adequate service during periods of peak demand to the remote user or to the consumer at the highest elevation. A 30-psi water pressure can be considered as the minimum for adequate service for the average consumer under the maximum conditions of water use. The allowable pressure drops must also be governed by residual pressures at fire hydrants, to meet the requirements of the National Board of Fire Underwriters. These requirements are being brought to our attention by the N.B.F.U. representatives and need not be repeated here.

Future planning is most vital to the water-works engineer. He should investigate different designs for a water-distribution system, whether it be a complete project or just a water-line extension. Be sure your line is large enough to insure future support to the existing interior grid system, even though this main is not going to serve its full capacity now. Do it now, because if you have to parallel this water line at some future date in sur-

faced streets, you will spend at least 20% more money than you spent in the initial installation.

In the planning of major extensions to the distribution system the water-works engineer should coordinate his plans closely with the city planning board and, if a master plan of the community exists, he should be guided by this future plan. Water mains, not based on a comprehensive community plan, can lead to future unanticipated problems and large expenditure of work and money, which may have to be duplicated. Industrial parks and suburban shopping centers make heavy demands on the water system and, as these are likely to occur in the fringe areas of the distribution system, it is up to the water-works executive to plan ahead to serve their needs. These industrial parks and suburban developments contribute greatly to the economic life of the city or town and, if at all possible, should be anticipated and adequately supplied with water. In the selection of a site for these modern industrial plants, an ample supply of good water is perhaps the most important factor.

Speculative land developers on the outskirts of the city are a growing concern of the water department. As time goes on, these developments which were once considered impossible, due to topographic and geological conditions, are now increasing in scope, due to the public demand for more housing. Modern earth-moving equipment has made it economically feasible to produce good building lots in areas once thought of as impossible terrain. If these developments would proceed in orderly and logical fashion, the water-supply problem would be simplified. If these developers could be persuaded to construct their projects in a continuous fashion, instead of leap-frogging over large undeveloped areas, the results would be of mutual benefit to them and the water works.

The trend towards larger lots in these new developments also necessitates the increase in main-pipe extensions to service the same number of water consumers. In the past, 500 ft of main pipe would service 20 houses with 50-foot lots; today eight lots of 125 ft are supplied by the same extension. These new owners take great pride in their lawns and expend a considerable sum in developing a lawn of good appearance. They use the lawn sprinklers continuously. Most of this sprinkling occurs during

the peak demand, which adds to the problem of the water works.

Duplication of facilities cannot be avoided all the time. These must be installed when highways are built over your system and when important changes in the land use of an area occur. Highway construction often necessitates costly changes to your system. Duplication is necessary to maintain service while construction of the new line is being completed. In this situation, be sure that you have pipe sizes with sufficient capacity, since any future revision would be very costly.

Money is a big problem in all our work. It is our job as engineers to see that the available funds are expended in such a manner that the system receives the greatest possible benefit. Remember that by increasing some of your water lines one pipe size, capacity can be increased by a percentage far in excess of the costs of such changes.

Standby equipment for emergencies, especially for the vulnerable functions of your system, such as pumps, auxiliary power, possibly a standby well, and duplicate chlorinating equipment should be planned for and, if possible purchased or constructed. A master operational plan for emergency situations, as might occur during a natural disaster such as a hurricane, flood or fire, should be formulated and rehearsed. This plan should be further implemented in the case of unnatural disaster, such as might occur during wartime. Close coordination of your organization should be sought with the Civilian Defense agencies. It is of paramount importance that your key personnel be aware of such a plan, so that they do not develop a lackadaisical attitude towards it.

As the water-supply system grows, all phases, including storage, purification and distribution, become more complex. Although the greater number of water works keep good records, it becomes more important that utility locations, street maps, and gate books be kept up to date in a simplified, legible and permanent form for the future operators of the water system. Most cities use the system of standard location for all utilities. A complete record of inaccessible water facilities is most valuable. Operating data, collected and plotted, so that comparison by year is feasible, are data that you will find useful when you start forecasting your future needs.

Time is an ever increasing factor in the repair and restoration of service due to main-pipe breaks. Although water-works crews have always responded as rapidly as possible to prevent damage and interruption of water service, larger mains carrying higher pressures make it more imperative that every possible minute be utilized to prevent serious washouts and damage to lives and property. Meat-packing plants, supermarkets, dairies and many other commercial and industrial properties are vulnerable with only a few hours' interruption of water service, due to lack of refrigeration and air conditioning. Also industrial plants with high-pressure boilers can suffer damage, not to mention the lack of fire protection. Two-way radios and 24-hour standby personnel are becoming a necessity to reduce the time factor in the restoration of the water supply. Closer valve spacing and the insertion of quick-closing, motor-operated gate or cone valves in strategic positions in the larger mains could minimize some of the effects of water damage.

Operational problems confront water-works management daily. How to deal with leaks in the distribution system? Should we have a meter-maintenance program? Should we clean and line mains with a known low carrying-capacity coefficient? What are we going to do in regard to water-quality problems? When are we going to start checking our gates on a routine schedule again? These and many others are present and must be solved.

If your "unaccounted-for water," which is "that portion of the water flowing into a distribution system which is not delivered to the consumers," is more than 25%, then you should start a leak-abatement program. Finding leaks is a problem, but one that can save you money. It is much cheaper to find leaks than it is to produce the water and waste it. The value of waste-water surveys can be shown by the many examples that exist today.

A meter-maintenance program is a fond dream to every water-works manager. Our industry is the only one in which the "cash register" gets such small attention and maintenance. Work out an economical, feasible, routine meter-repair program to fit your own situation, and watch to see how your "unaccounted-water account" drops. It has been shown also that after study, a good metering program will result in eliminating the immediate

needs in the development of additional sources of water supply.

Cleaning and lining those water lines that are old and known to be tuberculated is not the problem that it has been. Innovations in small water-main lining equipment and procedures have eliminated the many steps of preparation we had in shutting a section of our system down and out of service. A temporary water line to each customer is easily accomplished. Small water-main lining techniques should continue to improve and, with that, reduce costs. In many instances, savings in pump-operating costs have been achieved by cleaning and lining key mains.

Water-quality problems with regard to bacterial content, taste and odors, and the effects of corrosion constantly confront us. It is, therefore, necessary that the water-works engineer be acquainted with procedures to solve these problems.

Your foreman reported that several of the gates he tried to shut during the repair of a "pulled corp" weren't holding. This has occurred several times in the past. Lacking experienced personnel, you wonder when you can spare one good man and start a scheduled valve-inspection program. In the regular routine schedule of the department, time should be allotted for preventive maintenance of the plant, such as hydrant and gate-valve inspections, as well as other important appurtenances.

The water-works industry has cause to be aware constantly of the years of sub-normal rainfall and prolonged drought. However, the public, after a year or two of average or abnormal rainfall, soon forgets the so-called "lean years" and develops an apathy to the construction program of the water works.

It is the responsibility of the water-works management to keep reminding the public, the city fathers and the chief executive of the city that the lean years can occur again and with perhaps more severity than the past ones.

Every program of prevention of stream pollution should get the full support of the water-works engineer. Some of these streams have no significant water-supply potential at present, but the future demand for more water makes it imperative that all water resources be preserved.

As the water system of a community grows, the responsibilities of the water-works executive become increasingly greater. The public is becoming more and more demanding as to quality,

quantity and increased water pressures. The public health standards are also more exacting. The responsibility does not stop here, because we must be prepared to pass on to the future generations a system designed to meet the needs of the time. Both material and human resources should be adequate to meet the water-supply problems of the future.

# PROCEEDINGS

## February 1959 Meeting

## Hotel Statler-Hilton, Boston, Mass.

## Thursday, February 19, 1959

President Clarence L. Ahlgren in the Chair.

Secretary Knox announced the election of the following to membership in the association:

Victor M. Arrighi, Superintendent, Water Department, Easthampton, Mass.; Edward P. Egan, Jr., Registrar, Water Department, Easthampton, Mass.; Henry W. Buck, Consulting Engineer, Hartford, Conn.; Edward Forrest, Consulting Engineer, Sudbury, Mass.; John P. Keon, Chief Operator and Engineer, Walnut Street Pumping Station, Lynn, Mass.; William J. McGurl, Foreman, Water Department, Arlington, Mass.; Robert E. McQuade, Project Engineer, Camp, Dresser & McKee, Boston, Mass.; Paul H. Obear, Jr., Sales Engineer, The Bristol Co., Boston, Mass.; Charles E. Wheeler, Foreman, Water Department, Springfield, Mass.; Harry A. Faber, U. S. Public Health Service, Washington, D. C. (reinstated).

*Junior Member*

Allen E. Ferry, Student, Manchester, N. H.

*Corporate Member*

Vermont Water Conservation Board, Montpelier, Vt.

*Associate Member*

New England Chemical Supply Corp., Merrimack, N. H.

A paper on "Wachusett-Marlborough Tunnel for Metropolitan District Commission Water Supply" was read by Chester J. Ginder, Designing Engineer, Construction Division, Metropolitan District Commission, Boston, Mass.

A paper on "Steel Standpipe Reconstruction at Sanford,

Maine," was read by Robert L. Meserve, Project Engineer, Camp, Dresser & McKee, Boston, Mass.

A film, "Navy Frogmen," was shown by courtesy of the Public Information Office, First Naval District, Boston, Mass.

## March 1959 Meeting

### Hotel Statler-Hilton, Boston, Mass.

### Thursday, March 19, 1959

President Clarence L. Ahlgren in the Chair.

Secretary Knox announced the election of the following to membership in the association:

John J. Bargnesi, Water-Works Operator, East Lyme, Conn.; Paul L. Joyce, Superintendent, Water Department, Clinton, Mass.; Sylvan C. Martin, Regional Engineer, U. S. Public Health Service, New York, N. Y.; Robert L. Meserve, Project Engineer, Camp, Dresser & McKee, Boston, Mass.; Francis A. Riani, Water-Works Service Operator, Marlborough, Mass.

*Corporate Member*

Water Laboratory, National Institute of Sanitary Works, Caracas, Venezuela.

*Associate Member*

Adams Pipe Repair Products, El Monte, Cal.; E. H. Carroll Co., South Willington, Conn.

On motion of Richard H. Ellis, duly seconded, it was Voted that the last five living Past-Presidents, exclusive of those now serving on the Executive Committee—namely, Allan F. McAlary, Roger G. Oakman, William B. Duffy, Stanley M. Dore and Frederick O. A. Almquist—with Mr. Duffy as chairman, be elected to serve as the Nominating Committee for this year.

A paper on "The First Atomic Power Plant in New England" was read by Thomas M. Sherry, Engineer and Coordinator, Yankee Atomic Electric Co., Boston, Mass.

A paper on "Modern Trends in Sea-Water Conversion" was read by John J. Campobasso, Manager, Evaporator Division, Badger Meter Manufacturing Co., Cambridge, Mass.

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This *service* plus *always quality* merchandise at *reasonable* prices is maintained particularly for YOU. One of the most complete lines of "Everything for Water Service Work from Main to Meter" in New England. Our list of customers is constantly growing, if you are not one of them, join them.

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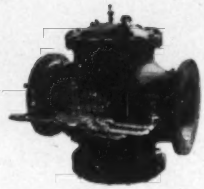
# 1879—ROSS—1879

## AUTOMATIC VALVES

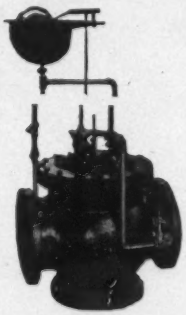


Controls elevation of water in tanks, basins and reservoirs

ALTITUDE VALVE
1. Single Acting
2. Double Acting

Maintains desired discharge regardless of change in rate of flow pressure

REDUCING VALVE
Regulates pressures in gravity and pump systems; between reservoirs and zones of different pressures, etc.



Maintains levels in tank, reservoir or basin

1. As direct acting.

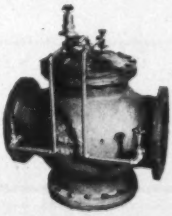
2. Pilot operated and with float traveling between two stops, for upper and lower limit of water elevation.

FLOAT VALVE

A self contained unit, with controls three or more automatic

COMBINATION VALVE
Combination automatic control both directions through the valve.

Maintains safe operating pressures for conduits, distribution and pump discharge



SURGE-RELIEF VALVE

Electric remote control—solenoid or motor can be furnished

REMOTE CONTROL VALVE
Adapted for use as primary or secondary control on any of the hydraulically controlled or operated valves.

ROSS VALVE MFG. CO., INC. Box 592 TROY, N. Y.

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DEPENDABILITY
with
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WATER METERS
WATCH DOG
GAMON METER DIVISION
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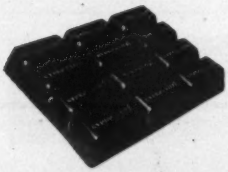
(POWDER)

For over 40 years HYDRO-TITE has been faithfully serving water works men everywhere. Self-caulking, self-sealing, easy-to-use. Costs about 1/5 as much as lead joints. Packed in 100 lb. moisture-proof bags.



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(LITTLEPIGS)

The same dependable compound in solid form — packed in 50 lb. cartons — 2 litters of pigs to the box — 24 easy-to-handle Littlepigs. Easier to ship, handle and store.

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(REELS)

The sanitary, bacteria-free joint packing. Easier to use than jute and costs about half as much. Insures sterile mains and tight joints.

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FITTINGS

*up to*

24 inches in stock

*Flanged pipe specials up to 20" made in our own shop.*

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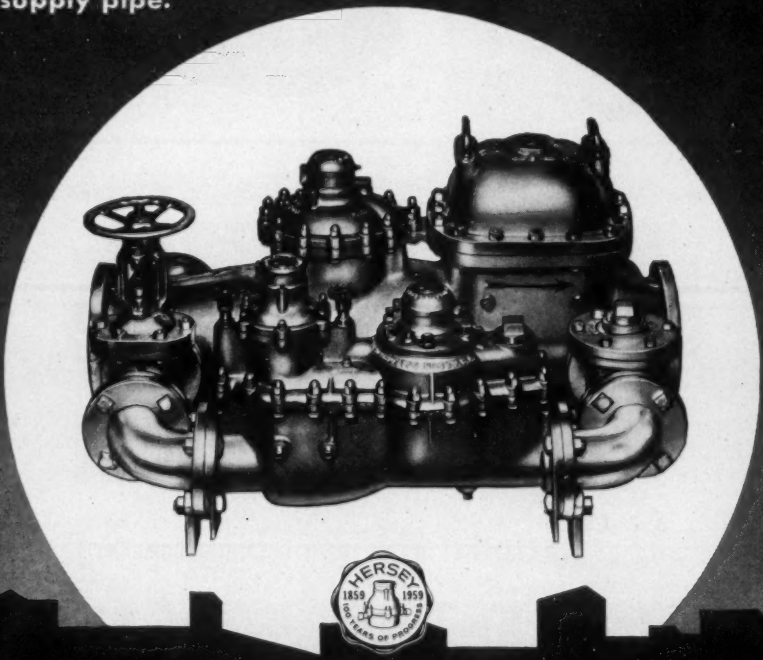
**Insure against loss of collectable revenue by accurately registering all rates of flow.**

**In emergency will deliver the full capacity of the supply pipe.**



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*here's what "out of sight out of mind" does to a water main*

"Out of sight—out of mind" can be a mighty expensive philosophy in any water distribution system. The above unretouched photograph proves this point. It shows a badly tuberculated *eight inch* main whose *inside diameter was reduced to an average of almost 4.5 inches.* Resultant higher pumping costs with reduced pressure and carrying capacity make it costly to tolerate such conditions. That is why the savings effected in reduced pumping costs frequently pay for the *low cost* of National water main cleaning.

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*Call in National today!*

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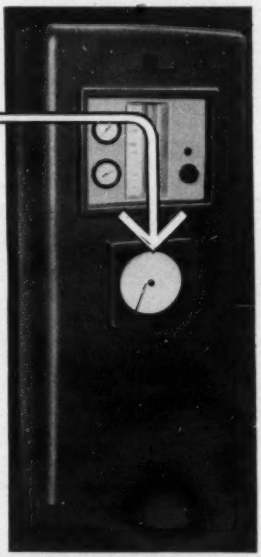
Vol. 195

announcing

# announcing

*a new chlorine flow recorder that's*

**BUILT IN FOR CONVENIENT USE**



**The W&T Series A-733 Chlorine Flow Recorder**

Now you can buy a compact new chlorine flow recorder that's mounted right in your chlorinator cabinet for convenient use —the Wallace & Tiernan Series A-733 Chlorine Flow Recorder.

This reliable recorder is designed for use with most V-notch Chlorinators. Its effective mechanical operation, made possible by the simplicity of the V-notch Variable-Orifice, assures an accurate record of chlorine flow.

The A-733's linear charts, calibrated to match the rotameter, have equally spaced graduations for easy reading. The charts provide permanent records useful to check the operation of equipment or the amount of chlorine fed during unattended periods. With the A-733, containers can't run dry: You know chlorine consumption to the pound.

An optional vacuum switch warns of any interruption of chlorine flow. It moves the recording pen to a check line and actuates an accessory alarm.

*See the new Series A-733 Recorder at Booth 184, AWWA Convention in July.*

Get more information today. Write for publication S-139.63

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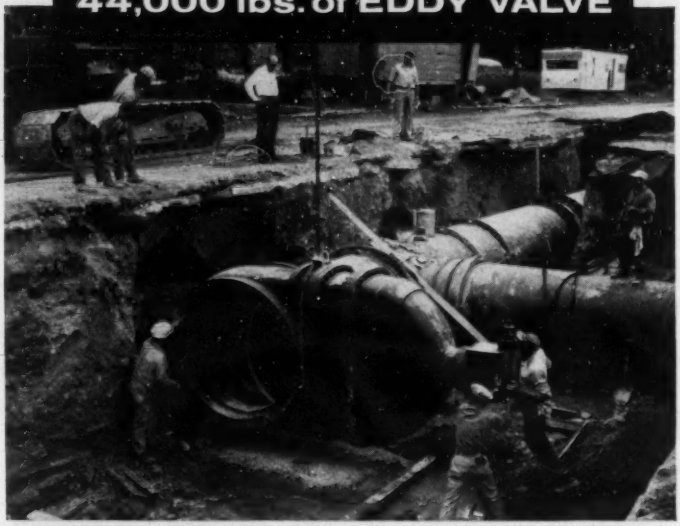
44,000 lbs. of EDDY VALVE



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As part of a major waterworks improvement program, three 60" and fourteen 48" 300 lb. test IBBM EDDY valves have been installed by Fago Bros., Contractors, for Buffalo, New York. Each 60" valve weighs 44,000 pounds; each 48", 21,500 lbs. These are BIG valves...and do a BIG job.

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# KENNEDY VALVE has a complete line of A.W.W.A. Standard Gate Valves . . .

## . . . that conform to A.W.W.A. specifications in all respects

FIG. 58
- Inside Screw
- Non-Rising Stem
- Parallel Seats
- Bell Ends

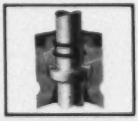
FIG. 571X
- Inside Screw
- Non-Rising Stem
- Parallel Seats
- Mechanical Joint Ends

FIG. 561
- Inside Screw
- Non-Rising Stem
- Parallel Seats
- Flanged Ends

FIG. 566
- Outside-Screw-and-Yoke
- Rising Stem
- Parallel Seats
- Flanged Ends

### Construction features . . .

**Conventional stuffing box**
with adjustable gland has ample space for packing that conforms to Federal specification HH-P-106c. The bottom face of the stuffing box flange is faced smooth to form bearing surface for stem thrust collar.



**O-Ring seals**
once installed no adjustment of any kind is required. The top O-Ring is the dirt seal and the bottom O-Ring is the pressure seal.

**Operating nut**
is Higher Strength Cast Iron. The base flange, with arrow indicating direction to open, is shaped to permit access from ground surface to adjust gland nuts with an extension socket wrench.

KENNEDY A.W.W.A. Standard gate valves are designed specifically for use in water works systems. Conforming to A.W.W.A. Specifications, in several particulars these valves exceed these standards of strength and refinements of design.

While A.W.W.A. Specifications cover only bell end and flanged end non-rising stem valves, the KENNEDY line also includes outside-screw-and-yoke valves and a wide variety of pipe connections including: Bell Ends, Flanged Ends, Mechanical Joint Ends, Universal Pipe Ends, Asbestos Cement Pipe Ends, Screwed Ends, Ring-Tite Pipe Ends and Spigot Ends.

In addition to standard features, KENNEDY A.W.W.A. Valves have reduction gearing, gear cases, by-passes, indicators and rollers, tracks and scrapers available on 16" and larger sizes. Gearing is always furnished on 30" and larger valves.

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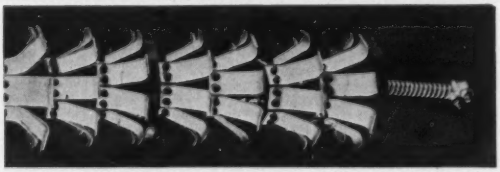
BOX 7 — GREENDALE BRANCH — WORCESTER 6, MASS.

50 YEARS IN 50 MINUTES



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Also, a complete sewer cleaning service is available.

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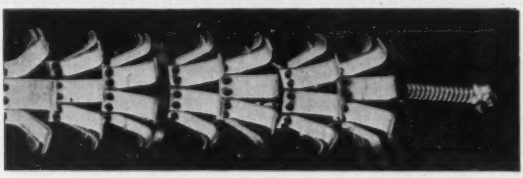

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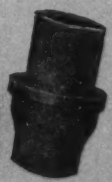
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